Rebuild by Design Living Breakwaters Project
Benefit Cost Analysis

Prepared for: New York Governor's Office of Storm Recovery

Action Plan Amendment 15

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Governor's Office of
Storm Recovery

Living Breakwaters Benefit Cost Analysis

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I. Executive Summary

This benefit cost analysis (BCA) was prepared for the Living Breakwaters: Tottenville Pilot Rebuild By Design Project (Living Breakwaters or the Project) by Louis Berger on behalf of the Governor's Office of Storm Recovery (GOSR). The project is located in the waters of Raritan Bay (Lower New York Harbor) along the shoreline of Staten Island, extending from Tottenville and Conference House Park, from Wards Point in the Southwest to Butler Manor Woods in the Northeast (Figure ES1).

The BCA was prepared following US Department of Housing and Urban Development (HUD) Benefit Cost Analysis (BCA) Guidance for Action Plan Amendments (APA) for Rebuild by Design (RBD) Projects (HUD CPD-16-06). The analysis used generally accepted economic and financial principles for BCA as articulated in OMB Circular A-94.

The Project consists of the following elements:

(1) A system of specially designed breakwaters and physical habitat enhancements on the breakwater system, including shellfish (oyster) restoration on the breakwaters, along with apportion of shoreline restoration;
(2) Oyster cultivation and activities supporting oyster restoration including: oyster cultivation (hatchery expansion, remote setting facility, etc.), shell collection and curing, and the installation of oyster nurseries;
(3) A community Water Hub and seasonal floating dock and boat launch. The Water Hub is an on-shore public facility that will provide a physical space for access to the waterfront as well as orientation, education and information on shoreline resiliency, community gathering space and equipment storage for NYC Department of Parks and Recreation maintenance. The Water Hub site would provide direct water access from shore by way of a seasonal floating dock; and
(4) Programming including educational, stewardship, and capacity-building activities related to the above.

The Project is designed to 1) Reduce coastal risk through decreasing exposure to wave action and associated erosion along the shoreline in Tottenville, Staten Island; 2) Enhance habitat functions and values supporting local ecosystems through the creation and improvement of near shore and coastal habitat; and 3) Foster stewardship, and recreational and educational use of the coast and near shore, through increased awareness, access, and participation.

The BCA indicates that the Project will generate substantial net benefits (i.e., the benefits exceed the costs over the life of the Project) to the shoreline community of Tottenville, Staten Island, New York, as well as other beneficiaries from the New York metropolitan region.

Figure ES1
Living Breakwaters: Tottenville Pilot Rebuild by Design Project Illustration

A discussion of the BCA results is provided below and the values are presented in **Table ES1: Living Breakwaters Project – Benefit Cost Analysis Summary** and **Figure ES1A**.

The BCA was completed using a 7% discount rate and a 50-year planning evaluation horizon. Using these parameters, the lifecycle costs to build and operate the Project (amounting to $62.4 million in constant 2016 present value dollars) would generate the following benefits:

- Total Benefits of $ 76.1 million, of which:
    - Total Resiliency Values are $ 53.2 million;
    - Total Environmental Values are $ 11.6 million;
    - Total Social Values are $ 8.3 million; and
    - Economic Revitalization Benefits are $2.95 million.

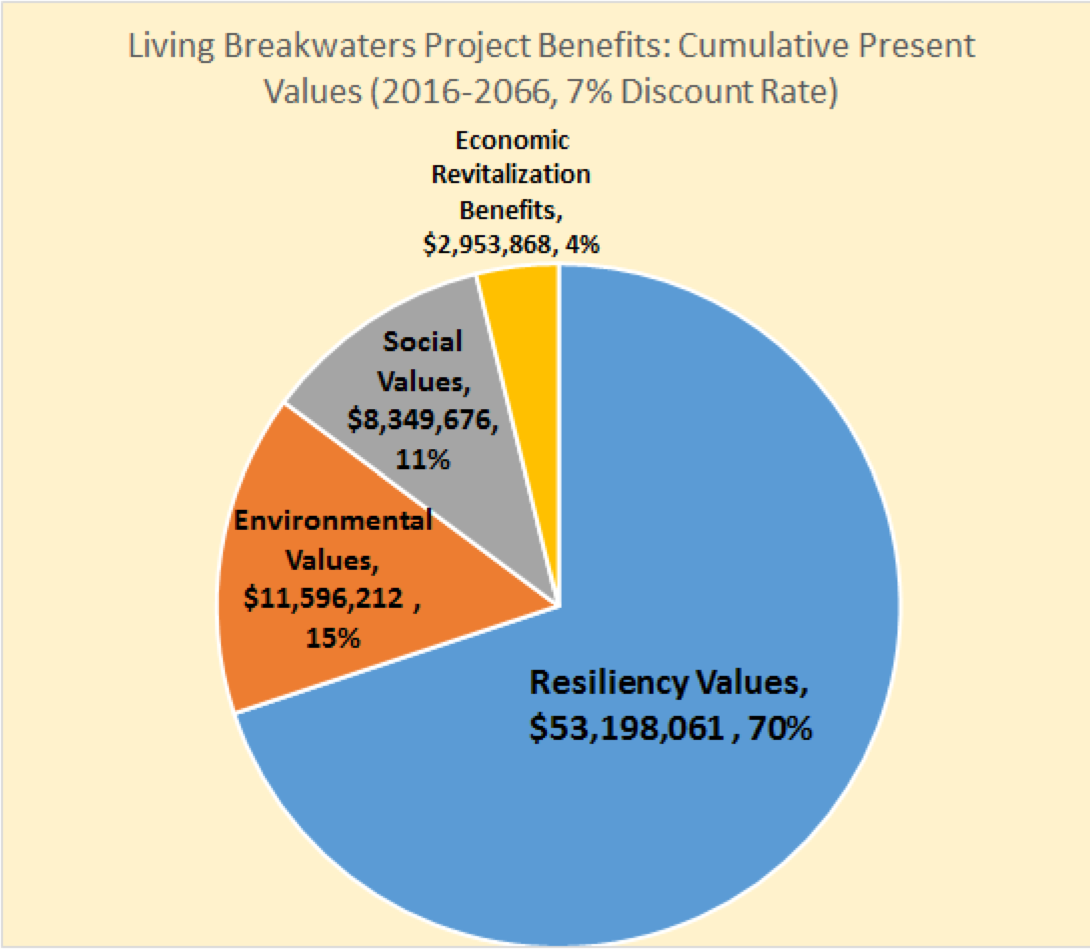
The Project's cumulative present value of net benefits (benefits minus costs) is $ 13.7 million, and the Benefit Cost Ratio (BCR) (Benefits divided by Costs) is 1.22. These net benefits demonstrate that the Project has merit and would add value to the community of Tottenville, Staten Island, New York, and provide benefits to other beneficiaries throughout the New York metropolitan region.

The Project's future annual benefit and cost streams, projected over the 50-year planning horizon, were subjected to a sensitivity analysis. The sensitivity analysis tested how key variables and parameters, if changed, would alter the economic feasibility of the Project, measured by the BCR and the net present value. The sensitivity analysis examined potential construction cost overruns and operation and maintenance (O&M) increases as well as substantial reductions in the largest benefit categories. The results showed that the Project's net present value of benefits is robust and can withstand these standard stress factors given the uncertainties that may arise, and remain economically viable over this period.

Table ES1: Living Breakwaters Project - Benefit Cost Analysis Summary Constant 2016 US Dollars		
	Cumulative Present Values (2016-2066) At Discount Rates of:	
	7%	**3%**
LIFECYCLE COSTS		
Project Investment Costs \a	$54,909,955	$61,150,787
Operations & Maintenance (O&M)		
Maintenance	$7,080,207	$14,507,755
Monitoring	$453,411	$829,867
Total O&M	$7,533,618	$15,337,622
Total Costs	**$62,443,573**	**$76,488,409**
BENEFITS		
Resiliency Values		
Avoided Property Damages	$4,888,646	$12,645,701
Avoided Casualties (Mortality & Injuries)	$2,859,166	$5,858,597
Avoided Mental Health Treatment Costs	$506,972	$965,226
Avoided Lost Productivity Costs	$1,128,405	$2,148,374
Avoided shoreline erosion/dune reconstruction costs	$41,858,316	$56,815,891
Avoided displacement/disruption costs	$526,326	$1,376,525
Avoided Road Closure/Travel Disruption costs	$315,901	$647,300
Avoided Cost of Power Outages	$1,050,543	$2,152,587
Avoided Vehicle Damages	$63,787	$189,399
Total Resiliency Values	$53,198,061	$82,799,601
Environmental Values		
Total Gross Ecosystem Annual Service Gains (+)	$11,860,749	$24,625,205
Total Ecosystem Annual Services Displaced (-)	$264,537	$509,059
Net Ecosystem Annual Service Gains	$11,596,212	$24,116,146
Social Values		
Educational/Environmental Stewardship	$1,253,995	$2,569,509
Recreation	$7,095,681	$14,539,461
Total Social Values	$8,349,676	$17,108,970
Economic Revitalization Benefits		
Property Value Impacts (ʃ[Distance and Beach Width])	$2,953,868	$6,052,646
Total Benefits	$76,097,817	$130,077,363
Benefits less Costs (Net Present Value)	**$13,654,244**	**$53,588,954**
Benefit Cost Ratio (BCR)	**1.22**	**1.70**

Notes:
Includes adjustment over time for 30 inch Sea Level Rise (SLR)
\a Note that because Project construction is anticipated to occur over 2018, 2019 and the first quarter of 2020, the present value calculation of costs (as of 2016) will appear to be lower than the nominal project investment costs shown in the Opinion of Probable Cost Document due to the application of the 7% HUD recommended discount rate

Figure ES2



Living Breakwaters Project Benefits: Cumulative Present Values (2016-2066, 7% Discount Rate)
Economic Revitalization Benefits, $2,953,868, 4%
Social Values, $8,349,676, 11%
Environmental Values, $11,596,212 , 15%
Resiliency Values, $53,198,061 , 70%

II. Introduction

The Rebuild by Design Living Breakwaters Project (Living Breakwaters or the Project) Benefit Cost Analysis (BCA) was completed by applying procedures described in the US Department of Housing and Urban Development (HUD) Guidance document CPD-16-06 for Rebuild by Design (RBD) projects. The analysis is also consistent with procedures and principles found in OMB Circular A-94. The analysis follows the "with without" project evaluation framework that is used to isolate the net benefits of the intervention.

<u>Future "With Project" Scenario</u>

In the *Future with Project Scenario*, the Project would be constructed, consisting of the following elements:

(1) A system of specially designed breakwaters and physical habitat enhancements on the breakwater system, including shellfish (oyster) restoration on the breakwaters, along with a portion of shoreline restoration;

(2) Oyster cultivation and activities supporting oyster restoration including: oyster cultivation (hatchery expansion, remote setting facility, etc.), shell collection and curing, and the installation of oyster nurseries;

(3) A community Water Hub and accessory seasonal dock. The Water Hub is an on-shore public facility that will provide a physical space for access to the waterfront as well as orientation, education and information on shoreline resiliency, community gathering space and equipment storage for NYC Department of Parks and Recreation maintenance. The Water Hub site would provide direct water access from shore by way of a seasonal floating dock; and

(4) Programming including educational, stewardship, and capacity-building activities related to the above.

Components of the project include a system of off-shore breakwaters engineered to provide maximum habitat and ecological restoration opportunities. In this scenario, the Project will:

1) Reduce coastal risk through decreasing exposure to wave action and associated erosion along the shoreline in Tottenville, Staten Island;
2) Enhance habitat functions and values supporting local ecosystems through the creation and improvement of near shore and coastal habitat; and
3) Foster stewardship and recreational and educational use of the coast and nearshore through increased awareness, access, and participation.

<u>Future "Without Project" Scenario</u>

In the *Future without Project Scenario*, the Project would not be built. If the Project is not constructed, the Tottenville, Staten Island shoreline would continue to be at increased risk of continued erosion and shoreline communities within the Limits of the Moderate Wave Action (LiMWA) zone would face the risk of damaging storm waves, as experienced during Superstorm Sandy. Without the construction of the

Project, the community may continue to lose parkland, and other open spaces and natural resources, and residents will continue to face the risk of bodily injury, loss of life, loss of property and damage to public infrastructure. These cumulative impacts would have a negative effect on the health and productivity of residents, and the economy.

The aquatic habitat of the bay adjacent to Tottenville would remain in its current state, characterized by a sand/gravel bottom condition with limited structured habitat to support the variety of fish, crustacean, bivalves and other benthic invertebrates identified as a priority in the Hudson Raritan Estuary comprehensive restoration plan. Shoreline habitat would remain subject to the disturbance and erosion effects of high-energy wave action during severe storms not attenuated by the project

Educational programming in Conference House Park and the Billion Oyster Projects programming in Staten Island would remain as is.

Key Analysis Aspects

This BCA quantifies risk reduction benefits (Resiliency Values), Environmental Values, Social Values and Economic Revitalization Values that would be generated by the Project per HUD Guidelines. Details on these categories of benefits are provided below. An overview of assumptions and data used for the BCA is included in Attachment A - Parameters and Assumptions Technical Memorandum.

The project evaluation time horizon is 50 years and the analysis applies the recommended 7% discount rate. The net benefits were also calculated using the 3% discount rate that is often applied in studies valuing environmental and ecosystem benefits. The BCA also includes a sensitivity analysis that assesses the change in net benefits (cumulative net present value) for various stress events and for a range of Project discount rates.

The analysis includes valuations based on physical point estimate quantities for projected habitats that provide ecosystem services and values obtained from peer reviewed literature that have been applied to value these resources using benefits-transfer techniques. It is noted that the Federal Emergency Management Agency (FEMA) has applied similar methods to value ecosystem services for environmental infrastructure projects or projects that remove obstructions to watersheds and floodplains to restore ecosystem services (FEMA, 2013).

III. Process for Preparing Benefit Cost Analysis

This BCA was prepared by Louis Berger U.S, Inc. (Louis Berger) using inputs provided by the Governor's Office of Storm Recovery (GOSR) and the Living Breakwaters design team including SCAPE Landscape Architecture, Ocean and Coastal Consultants COWI, WSP Parsons Brinckerhoff, the NY Harbor Foundation, MFS Engineers & Surveyors , Arcadis, and GOSR's consultant preparing the environmental review for the Project, AKRF. Louis Berger provided guidance and analysis on various sections of the BCA including expertise in resilience, landscape design, coastal and environmental engineering, ecology, economic analysis, geographic information systems, project evaluation, engineering economics and socio-economics.

The BCA relied on inputs, data and information from the Living Breakwaters design team as well as information on the project area and information from GOSR, and information transmitted through the authors of the environmental impact statement (EIS). In addition, Louis Berger applied its own research findings, collective multidisciplinary expertise, experience, and professional judgment in completing the BCA on behalf of the State of New York.

IV. Proposed Funded Project

The integrated purposes of the Living Breakwaters Project are threefold:

1) to reduce coastal risk through decreasing exposure to wave action and associated erosion along the shoreline in Tottenville, Staten Island;

2) to enhance habitat functions and values supporting local ecosystems through the creation and improvement of near shore and coastal habitat; and

3) to foster stewardship and recreational and educational use of the coast and nearshore through increased awareness, access, and participation.

The Project is an innovative coastal green infrastructure project that aims to increase physical, ecological, and social resilience. The project is located in the waters of Raritan Bay (Lower New York Harbor) along the shoreline of Staten Island. The affected shoreline extends from Tottenville and Conference House Park, from Wards Point in the Southwest to Butler Manor Woods in the Northeast. The project area is a shallow estuary that has historically supported commercial fisheries and shell fisheries. The Project consists of the following main elements (SCAPE, FDR30 Percent, 2016):

(1) A system of engineered breakwaters and physical habitat enhancements on the breakwater system, including shellfish (oyster) restoration on the breakwaters, along with a portion of shoreline restoration;

(2) Oyster cultivation and activities supporting oyster restoration including: oyster cultivation (hatchery expansion, remote setting facility, etc.), shell collection and curing, and the installation of oyster nurseries;

(3) A Water Hub - an on-shore public facility (building and site) to house educational programs, community stewardship activities, science and monitoring efforts, recreational program and equipment and exhibitions related to the project and its objectives of risk reduction and resilience, ecological enhancement and community building; and

(4) Programming including educational, stewardship, and capacity-building activities related to the above.

Project Schedule, Useful Life and Discount Rate:
Project construction is anticipated to start in mid-2018 and continue through the first quarter of 2020. For the purposes of this BCA, a 19-month construction schedule is assumed. This period factors in fish and crab spawning months that may prevent certain construction activities from occurring during certain times of the year. This assumption is consistent with conservative economic modelling principles applied in BCA. The BCA also assumes a 50-year project evaluation time horizon. A discount rate of 7%, recommended by HUD and per OMB Guidelines, has been applied. The BCA also presents, for comparison, the main results by BCA element applying a 3% discount rate. The 3% discount rate has previously been applied in economic analysis of environmental infrastructure projects (Freeman, 1999).

V. Full Project Cost

The nominal base Project cost without contingencies is estimated to be $66.5 million. Applying a 30 percent contingency to the base cost, the estimated cost would be $79.1 million. The cumulative present value of estimated O&M plus periodic monitoring is $7.5 million. On an annual worth equivalent basis, using a 7% discount rate over a 50-year period, these cumulative O&M and monitoring costs would be approximately $550,000 per year.

VI. Current Situation and Problem to be Solved

The need for enhanced erosion protection, wave attenuation, and social resiliency were demonstrated during the severe storm events of 2011 and 2012 (including “Superstorm Sandy” in 2012) when the Tottenville, Staten Island community experienced severe damage from storm waves. In addition to storm events, the shoreline has experienced ongoing erosion over the last 35 years. While shoreline change patterns oscillate between erosion and accretion, most of the shoreline in the project area has experienced erosion. In many locations, erosion rates average over one foot per year and in one section of the Conference House Park shoreline, the average rate of erosion is 3 feet per year. To put these rates into context, **Figure 1** depicts the historic shoreline change in part of the project area over the past 35 years.

Figure 1: Historic long-term shoreline change

(Source: SCAPE, FDR 30 Percent, 2016)

The need for habitat enhancement within Raritan Bay has been well documented through ecological assessments and reports including *National Marine Fisheries Service Raritan Bay* habitat evaluations and the *New York State Department of Environmental Conservation Shellfish Assessments* developed for the Food and Drug Administration in support of their northern quahog (Mercenaria mercenaria) fishery and the *New York – New Jersey Comprehensive Restoration Plan for New York Harbor* (HRE-CRP).

The Project is taking a thematically and spatially layered approach to reducing coastal risk, restoring and enhancing habitats important to local ecosystems, improving water access, and engaging with residents through community and educational programs directly related to the project's coastal and ecological resilience efforts. The project is consistent with New York City's Coastal Protection Initiatives and planning studies for the Tottenville area as well as the HRE-CRP. The efforts and objectives were guided by the harbor-wide assessment of habitats, and their functions and values used in the drafting of the *Comprehensive Restoration Plan* (SCAPE, FDR30 Percent, 2016, Bain et. al., 2006).

VII. Risks Facing Project Area Community

Without the Project, the Tottenville community would continue to face risks associated with the ongoing erosion of shoreline, vulnerability to unbridled wave action and destructive wave energy, and ongoing susceptibility to future damages and social dislocations. These types of impacts were experienced and most noticeable during the severe storm events of 2011 and 2012 (including "Superstorm Sandy") when the Tottenville, Staten Island community experienced severe damage from storm waves. However, it is apparent that without the Project, ongoing changes to the community's shoreline will affect quality of life going forward. In addition to storm events, the shoreline has experienced ongoing erosion over the last

35 years at rates depicted in **Figure 1**. While shoreline change patterns oscillate between erosion and accretion, most of the shoreline in the project area has experienced erosion. If unaddressed, these erosion patterns can alter the character of the community and generate ongoing costly maintenance and restoration activities in the future. Narrower beaches mean decreased protection from wave action, greater exposure of shoreline features such as dunes to erosion and loss of important shoreline public space. In fact, some segments of the Tottenville beach are not accessible at high tide, and with the current rates of erosion and sea level rise (SLR), the extent of these zones will only increase.

VIII. Benefits and Costs

a. Lifecycle Costs

The lifecycle costs of the intervention over the Project's lifetime are necessary for the BCA and to determine economic feasibility (i.e., whether the cumulative present value of the Project benefits exceed the cumulative present value of costs over this period). The Project's lifecycle costs consist of both project investment costs (upfront capital construction costs) and long-term annually recurring operations and maintenance costs. In addition, regulatory related monitoring costs are included for the first five years of operations, and additional monitoring costs (for breakwaters structure plus oyster reef) are modelled to recur at less-frequent periodic intervals (every 5 years thereafter) extending out over the 50 year project time horizon. Periodic monitoring costs associated with structural integrity monitoring and assessment of the breakwaters will be incurred. Furthermore, scientific monitoring and sampling/upkeep of ecological restoration efforts will be necessary. These activities will incur costs related to monitoring of the oyster habitat and colonization growth over time to ensure that the goals and objectives of the Project are being realized.

Project investment costs were obtained from the Opinion of Probable Cost (OPC) for the 30 Percent Living Breakwaters Design (SCAPE, OCC & MFS, 2016). **Table 1** shows the breakdown of the Project capital investment costs.

Table 1: Living Breakwaters Project – 30 Percent Design Scenario Opinion of Probable Cost (OPC)

	Base OPC (No Contingency)	Recommended OPC with 30 Percent Contingency
Breakwaters Only	$56,400,000	$67,900,000
Additional Line Items	$10,100,000	$11,200,000
Breakwater Project Total:	**$66,500,000**	**$79,100,000**
Source: (SCAPE OCC MFS, 2016)		

A sensitivity analysis provided in Section IX.b. includes the net benefits and BCRs calculated with full contingencies and simulated construction cost overruns as part of a stress test. In addition, project work files include the full Project Resource Statement MS Excel worksheet created for this Project. The Project Resource Statement appendix contains the capital cost phasing applied over the periods 2018 to 2020.

O&M costs were estimated on an annually recurring basis. These costs relate to operating the water hub building and to operating the breakwaters and oyster reef installation activities. These costs are for annual sustainment required for the breakwaters structure and for oyster restoration/colonization activities. Project annual O&M costs were estimated by multiplying 0.95% of the Base OPC capital cost shown in **Table 1**. This technique has been applied at the 30 percent design phase for capital investments. Using this factor results in an annually recurring O&M cost of approximately $633,000 per year. For this BCA, it is assumed that O&M costs would start in the year 2020 (post-construction activities scheduled for Q1). The BCA assumed that periodic monitoring per permitting compliance would occur for the first five years, and then recur at five (5) year intervals, thereafter at a cost of $150,000 per year.

As a frame of reference for the water hub, Louis Berger compared the annual operations cost of the Alley Pond Environmental Center (APEC)- a facility with a dedicated nature and watershed educational structure, and interpretative space that provides exhibits, aquariums, and classroom facilities, and is supported by utilities and dedicated staff. The APEC also operates an educational and community outreach program. The annual O&M costs calculated for the Living Breakwaters Project were within a reasonable range of the annual sustainment costs experienced by the APEC facility per recent financial statements (APEC, 2016).

As mentioned above, the Project's investment costs (capital construction) were sourced from the Opinion of Probable Cost document for the Project's 30 Percent Design ($66.5 million). To calculate the BCR, the construction costs were phased in over a 19-month period spanning the years 2018-2020 per the anticipated construction schedule provided by GOSR.

b. Resiliency Values

Resiliency values are the benefits that capture risk reduction, and the risk avoidance and property and infrastructure protection values offered by the Project. Under the Future with Project scenario, these values are determined from avoided costs that would have been incurred under the Future without Project scenario (in the absence of the Living Breakwaters Project). An avoided cost that would no longer be incurred under the Future with Project situation is counted as an annual benefit in economic analysis.

i. Reduction in Expected Property Damages

<u>Introduction</u>

Mitigated damages to property structures and building contents, and mitigated disruption and displacement costs, were quantified using a methodology that compared damages and costs of various storm events in the Future with Project and the Future without Project scenarios. In the Future with Project scenario, the Project was assumed to be constructed and would have benefits with the existing dune assumed to be 9 feet NAVD88. In the Future without Project scenario, the Project was assumed to not be constructed but the effects of the existing dune were still considered. Thus, the mitigated damages and costs quantify the benefits for the Living Breakwaters Project assuming the existing dunes are in place. The storm intervals analyzed as part of the BCA include a 10-year, 25-year, 50-year, and 100-year storm events, their anticipated flood levels, and waves for both current and projected 30-inch sea level rise. All assumptions were taken from Attachment A noted above.

Within the BCA, the avoided damages from storm events are calculated using the *Expected Annual Damages* (EAD) framework. The EAD framework takes a weighted average sum of multiple storm events (of differing magnitudes and annual chance occurrences) and depicts these values as one annual-avoided-damages figure within the **Project Resource Statement** applied to calculate the BCR (Louis Berger).

The results of the Project's 30 Percent Design Report were used to determine the benefits of the Project based on a reduction of wave energy.

The Project attenuates wave energy and lowers incoming wave heights up to a 100-year storm event. The existing dune offers protection from water levels associated with frequent and small storm events and sea level rise less than 9 feet. The analysis assumed that the dune would not experience erosion during a storm. However, avoided maintenance costs of the dune was accounted for in a subsequent analysis, The Project attenuates wave energy and lowers incoming wave heights. While the existing dune provides some baseline flood protection, the Project enhances the existing dune's benefits by lowering incoming wave heights, thereby enabling the dune to more effectively protect against more severe storms and slowing or preventing erosion of the dune itself. In addition, the Project mitigates the impacts of waves on the shoreline, which lowers shoreline maintenance costs.

Methods & Data Applied

An approach using geographic information systems (GIS) was utilized to quantify the benefits and costs. The approach utilized ArcGIS and GIS layers to determine real properties affected by storm events. The resulting data was used to quantify the damages and cost. The approach is similar to those utilized by HAZUS[1] and FEMA's standardized methodology for estimating potential losses. While compatible with the aforementioned approaches, the approach used for this study provides for greater specificity as it relates to the *types* of damages quantified, the *data* used to quantify the damages, and the *storm events* studied. Because the two methodologies are similar as both utilize depth damage functions (DDFs), similar results are expected. The data sets used for this BCA are described below:

FEMA Preliminary Flood Hazard Data

FEMA provides map products that outline areas susceptible to floods and wave damages for 100-year and 500-year events. FEMA provides preliminary versions of these map products that give users an early look at a community's projected risk to flood hazards. Because this study assesses mitigated damages and costs under future scenarios when the Project would be built, the preliminary versions of these map products were used since they better represent future scenarios.

[1] Hazus is a nationally applicable standardized methodology that estimates potential losses from earthquakes, hurricane winds and floods. The Federal Emergency Management Agency (FEMA) developed Hazus under contract with the National Institute of Building Sciences (NIBS). (https://www.fema.gov/hazus-mh-overview)

USACE North Atlantic Coast Comprehensive Study Depth-Damage Functions

The USACE North Atlantic Coast Comprehensive Study included a Physical Depth Damage Function Summary Report Appendix. The appended analyses was the result of a workshop that developed depth-damage relationships by soliciting opinions from expert panelists including coastal and structural engineers, appraisers, restorers, and catastrophe modelers from the insurance industry (NACCS, 2015). In the workshops, the panelists utilized their experience and expert knowledge on recent storm events to quantity the depth-damage relationships. The quantified depth-damage relationships, called depth damage functions (DDFs), are used in USACE implementation studies and help reduce the studies' duration and costs. The depth-damage functions quantify the physical damages to building structures and contents caused by various storm events. The depth-damage functions provide damages as a percentage of the property value, dependent on the inundation depth or wave height. The curves estimate a structure and contents damage value as a percentage of market value based on the depth of inundation or wave height. As mentioned above, the damages are then expressed as expected annual damages (EAD) and take into account the various annual probabilities of storm events of varying magnitudes and annual chances of occurrence. As a simplifying assumption, the depth damage functions do not consider the following to be factors in the damage analysis: age of building, basement use, construction quality, city codes, dune or seawall presence, lobby layout, backwater valves, and layout of mechanical, electrical and plumbing systems.

NYC Department of Finance Assessment Rolls

Property values in the study area were obtained from assessment rolls provided by the NYC Department of Finance. The assessment rolls are official databases updated annually that include detailed information about New York City property, including assessed and market values. The assessment rolls include data for all tax classes, defined as follows:

- Tax Class 1: Residential property up to three units and condominiums no more than three stories
- Tax Class 2: Residential property larger than those defined for Tax Class 1
- Tax Class 3: Utility property
- Tax Class 4: Commercial or industrial property

NYC Department of City Planning MapPLUTO

The location of each property defined in the assessment rolls were identified using NYC Department of City Planning's MapPLUTO data. MapPLUTO data are ArcGIS shapefiles that delineate the outline of each property as defined by the NYC Department of Finance's Digital Tax Map. MapPLUTO data also includes extensive land use and geographic data for each property.

Property Structure and Content

Damage to structures and their contents are a key component of storm event and wave damages. Structures and their contents constitute the financial assets of property owners and tenants, and damages to these assets negatively affect the economic well-being of affected individuals. Damages can be incurred from flooding that inundates the structure and its contents or wave action that causes structural damage. The magnitude of damages to structures and contents are proportional to the flooding depth of the structure and can be modeled as a percentage of the property value. Depth-damage functions depict this mathematical relationship between the flood depth and the percent damage. Depth-damage functions from the USACE North Atlantic Coast Comprehensive Study can also be used to estimate damages from waves based on wave depth at the structure.

Methodology

Storm Events and Wave Impacts

The BCA has quantified damages to structures and contents for properties mitigated by the Project. As stated above, mitigated damages for the 10-year, 25-year, 50-year, and 100-year storm events, and their related flood and wave impacts for both current and projected 30-inch sea level rise scenarios, were quantified. Water levels and wave heights assumed for each event are depicted in **Table 2** below.

Table 2: Storm Events and Wave Impacts						
			"today"		With 30" sea level rise	
Return Period	Annual Chance	Time Period	Stillwater Elevation (feet, NAVD88)	Significant Wave Height (feet)	Stillwater Elevation (feet, NAVD88)	Significant Wave Height (feet)
10 year	10%	Today	8.1	3.9	10.6	3.9
25 year	4%	Today	9.3	4.3	11.8	4.3
50 year	2%	Today	11.3	4.9	13.8	4.9
100 year	1%	Today	12.9	5.3	15.4	5.3

Depth-damage functions specified in USACE's *North Atlantic Coast Comprehensive Study* (NACCS) were used. Separate depth-damage functions were used for residential and commercial properties, and for flood and wave damages. For residential properties, the analysis utilized the depth damage function for a single story apartment with no basement. This depth damage function was used in the analysis because the values were lower than that of a single story residence. Thus, this assumption would provide a conservative estimate of the benefits. Approximately 40% of residential properties in the study area have more than one residential unit. For commercial properties, the analysis utilized the depth damage function for engineering commercial construction. The values in the depth damage function for the "Most Likely" scenario was used. **Tables 3 thru 6** depict these depth-damage functions.

Table 3: Residential Properties – Structure and Content Damages from Inundation as a Percentage of Property Value		
Inundation depth (ft)	**Structure Damage (%)**	**Content Damage (%)**
-1	0%	0%
-0.5	0%	0.0%
0	10%	4%
0.5	16%	14%

Table 3: Residential Properties – Structure and Content Damages from Inundation as a Percentage of Property Value		
Inundation depth (ft)	**Structure Damage (%)**	**Content Damage (%)**
1	25%	28%
2	35%	45%
3	43%	60%
5	60%	81%
7	68%	100%

Table 4: Commercial Properties – Structure and Content Damages from Inundation as a Percentage of Property Values		
Inundation Depth (ft)	**Structure Damage (%)**	**Contents Damage (%)**
-1	0%	0%
-0.5	0%	0.0%
0	5%	5%
0.5	10%	18%
1	20%	35%
2	30%	39%
3	35%	43%
5	40%	47%
7	53%	70%
10	58%	75%

Table 5: Residential Property – Structure and Content Damages from Waves as a Percentage of Property Values		
Wave Crest Depth (ft)	**Structure Damage (%)**	**Content Damage (%)**
-1	0%	0%
0	0%	3.5%
1	25%	30%
2	38%	50%
3	90%	90%
5	100%	100%

Table 6: Commercial Property – Structure and Content Damages from Waves as a Percentage of Property Values		
Wave Crest Depth (ft)	**Structure Damage**	**Content Damage**
-1	0%	0%
0	0%	3.0%
1	9%	18%
2	20%	30%
3	33%	41%
5	55%	75%
7	65%	95%
10	82%	95%

The mitigated damages for the project were quantified as the difference between the damages under the Future without Project Scenario and the Future with Project scenario. For the Living Breakwaters project, the wave reduction scenario as modeled in the *Final 30 Percent Design Report* was used. The existing dunes were assumed to have a crest elevation of 9 feet NAVD88, which was the average elevation along the dune alignment. The dunes also provide wave reduction, since we can assume that the maximum height of a wave is reduced to 78% of the water depth above any feature based on FEMA's Guidance for Flood Risk Analysis and Mapping.[i]

For both the Future without Project and the Future with Project scenarios, there are two possibilities: properties would not flood due to their ground elevation, or properties would flood and incur damages from waves and inundation. In the Future with Project scenario, the inundated properties would experience a lower wave depth than in the Future without Project scenario because of the wave reduction effects of the Project. Wave damage was assumed only for properties in the Preliminary FEMA Zone V. For today's scenario, no buildings were located in the Preliminary FEMA Zone V. For the 30" sea level rise scenarios, a "future" Zone V was estimated by adding 30" to the ground elevation at the landward extent of the Preliminary FEMA Zone V. The buildings within this "future" Zone V are shown in **Figure 2** below. The Zone V (used for 100-year storms) was assumed to be the same for other storm events. All buildings, in addition to the first row of buildings landward of Raritan Bay, were assumed to experience wave damage.

Figure 2: Buildings in Potential Future Zone V (Assuming 30" Sea Level Rise)

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

This logical framework for estimating inundation and wave damages is depicted in **Figure 3** below. The framework in this diagram is used for both residential and commercial values and for both Without and With project scenarios. The difference in the mitigated damages of each scenario reflects the mitigated risk of the Project.

Figure 3: Logical Framework for Calculating Damages for Each Property

<u>Results</u>

The mitigated damages for each event as described above are shown in **Table 7** below. Mitigated damages would be incurred for today's 100-year storm event and for the 50 year and 100 year storm events with 30" sea level rise. For all other storm events, the existing dune would provide sufficient wave attenuation to prevent wave damage to buildings, even without the breakwaters. Without the breakwaters, the dune could be lost due to wave damage and erosion, however for the purposes of the benefit cost analysis, it is assumed that the dune is maintained in good condition and the avoided costs of this maintenance with the project are included in the section below on avoided shore erosion / dune reconstruction.

As the severity of the storm event increases, the mitigated damage increases due to the prevented geographic extent and inundation and wave depth. This is because as the geographic extent and inundation depth of properties increase with the severity of the storm depth; more properties are affected and each property is affected more for high severity events. Thus, mitigation of higher severity storm events would result in the mitigation of both a higher count of properties and extent of damages for each property.

Table 7: Mitigated Damages to Structures and Contents from Inundation and Waves

Return Period	Annual Chance	Time Period	Mitigated Damages for Residential Properties (MD)	Mitigated Damages for Commercial Properties (MD)	Mitigated Damages for All Properties (MD)	EAD: Expected Annual Damages
100 year	1%	Today	$5,689,880		$5,689,880	$56,899
50 year	2%	With 30" sea level rise	$28,931,890	$441,900	$29,373,790	$587,476
100 year	1%	With 30" sea level rise	$84,074,417	$898,530	$84,972,947	$849,729

The Expected Annual Damages converts the total mitigated damages per storm event to the annual chance equivalent. The annual damages were entered into each respective year over the 50-year evaluation period. The 2016 value was the base year. For subsequent years' annual chance expected damages, the intervening years were calculated by applying linear interpolation from the base year up to the expected year that would experience the 30 inches of sea-level rise. Therefore, the sum total per year (t) for EAD_t damages would be equal to the following combination of risk adjusted damages ([MD] x [1/Return Period]) shown in **Equation 1**.

$$EAD_t = \Sigma\ ([MD_{100\ yr.}\ x\ 1\%] + [MD_{50\ yr.}\ x\ 2\%] + [MD_{100\ yr.}\ x\ 1\%] \qquad \textbf{(Equation 1)}$$

ii. Reduction in Displacement Costs

During storm events, tenants of both residential and commercial properties are forced to evacuate their homes and businesses. Displacement costs consist of the damages associated with this forced-evacuation. The displacement cost consists of "a one-time disruption cost along with a recurring monthly rental cost for the duration of the displacement." (FEMA, 2011)

Methodology

The BCA quantified displacement costs that would be mitigated by the Project. Mitigated damages for each storm event outlined in the **Property Structure and Contents** section above were quantified. The FEMA BCA methodology for quantifying displacement costs was applied for this task. As described above, displacement costs represent the sum of a one-time disruption cost and a recurring displacement cost for the duration of displacement. This relationship is shown in **Equation 2** below.

$$\begin{gathered} Displacement\ Cost = (Disruption\ Cost * \ Floor\ Area) \\ +(Rental\ Cost * Floor\ Area * Duration\ of\ Displacement) \end{gathered} \qquad \textbf{(Equation 2)}$$

The displacement cost was assumed to be linearly proportional to the rental cost of the building. Both rental costs and disruption costs were estimated as a per-square-foot value dependent on the occupancy type: single-family residential, multi-family residential, or commercial. These per-square-foot values were obtained from the FEMA Benefit-Cost Analysis Re-engineering document and are shown in **Table 8** below (FEMA, 2011). The duration of displacement was assumed to be dependent on both occupancy type and inundation depth and is shown in **Table 9** below.

Table 8: Rental Costs and Disruption Costs by Occupancy Type				
Occupancy Type	**Rental Cost (2008, $/sq. ft./month)**	**Disruption Costs (2008, $/sq. ft.)**	**Rental Cost (2016, $/sq. ft./month)**	**Disruption Costs (2016, $/sq. ft.)**
Single Family Area	0.73	0.88	0.82	0.99
Multi Family Area	0.65	0.88	0.73	0.99
Retail Trade Area	1.25	1.16	1.40	1.30

Table 9: Duration of Displacement by Occupancy Type and Inundation Depth				
Occupancy Type	Displacement for 0' - 4'	Displacement for 4' - 8'	Displacement for 8' + (Inside FP)	Displacement for 8' + (Outside FP)
Single Family Area	12	15	24	18
Multi Family Area	14	15	18	24
Retail Trade Area	14	15	18	24

The square foot floor area of each building within the affected areas were obtained from *NYC Department of City Planning's MapPLUTO* data. The data also contained land use information used to determine the occupancy type of each building. The methodology outlined in the **Property Structure and Content** section above was used to determine the water levels at each property in each storm event scenario.

Results

The mitigated damages for each storm event are shown in **Table 10** below. Both the existing dunes and the Living Breakwaters Project contribute to the mitigated costs due to their flood prevention and wave reduction effects. The Expected Annual Damages are shown below in **Table 10**. Similar to the mitigated property structure and content damages, mitigated displacement costs were incurred only for the 50 year and 100 year storm events with 30" sea level rise. In these storm events, the Project provided wave energy reductions that resulted in a quantifiable reduction in displacement and disruption time.

Table 10: Mitigated Displacement Costs						
Return Period	**Annual Chance**	**Time Period**	**Mitigated Damages for Residential Properties**	**Mitigated Damages for Commercial Properties**	**Mitigated Damages for Commercial Properties**	**EAD: Expected Annual Damages**
50 year	2%	With 30" sea level rise	$2,161,535	$157,250	$2,318,785	$46,376
100 year	1%	With 30" sea level rise	$8,076,002	$8,764	$8,084,766	$80,848

iii. Reduction in Expected Casualties (Mortality and Injuries)

Projected Mortality and Injury Estimates

Mortality estimates were developed assuming impacts would be comparable to those for a Superstorm Sandy type event and a 100-year storm return period extrapolated over the 50-year project evaluation period (planning horizon). The historical record was examined and two individual deaths were reported for the Tottenville section of Staten Island (Annese, 2012). These Sandy deaths were related to individuals being carried away by the storm due to wave damage to the structures they occupied. Drowning deaths can result from high velocity of destabilizing moving water enhanced by wave action. Furthermore, injuries such as lacerations can result as storm victims are pushed into sharp objects by moving water enhanced by waves. Therefore, the BCA includes likely avoided mortality benefits and associated injuries that would be attributed to the wave attenuation properties of the Living Breakwater Project. The Expected Annual Damages calculation applied for this BCA over the 50-year project evaluation horizon is based on the 1% annual chance event. The adjustment factor calculation adjusts the total Value of Statistical Lives (VSL) monetary estimate for two expected deaths by a 1% factor (return period reciprocal: 1/100) each and every year over the projection period. The 1% factor is also applied to the estimated projected injuries.

Parameters and Assumptions Applied

Table 11 shows key parameters and assumptions applied in the mortality and injury estimates.

Table 11: Parameters and Assumptions Applied in Mortality and Injury Estimates		
	Parameters	**Value**
	Discount Rate	0.07
\a	Expected Fatalities avoided:	2
	Storm event return period	100
	Annual 1% chance storm	0.01
	Fatality Rate (% of base population at risk)	0.274%
\b	Injury Rate:	10.4%

The fatality rate, shown in **Equation 3** was calculated as the number of reported deaths divided by the estimated population at risk shown below in **Table 12**. This fatality rate was applied to the projected population at risk over the projection period time horizon.

Fatality Rate = [2 / 730] x 100 = 0.274% **(Equation 3)**

Population at Risk

Analysis of the population at risk was based on the historical record and the base population for the number of households located within the FEMA at risk zone for the Tottenville, Staten Island project area.

A buffer area was applied to account for residents impacted by Superstorm Sandy who were also injured from the storm event, and were located adjacent to FEMA designated zones, but outside of the flood risk zones (CDC, 2014). **Table 12** shows the data that was used to estimate the population at risk.

Table 12: Data Applied to Estimate Population at Risk		
Data	Value	Source
Avg. HH Size	2.99	2010 Census, Tottenville/EIS
Residential Units (FEMA zone + buffer)	244	
Estimated At Risk Population	730	

Population Growth Rates

The population growth rates applied to the base population at risk in the projections were sourced from New York Metropolitan Transportation Council's (NYMTC) population projections for Traffic Analysis Zone (TAZ) 2206 (NYMTC, 2016). **Table 13** shows the population levels for this TAZ corresponding to the Tottenville, Staten Island area, and the annual growth rates calculated.

Table 13: Projected Population for TAZ 2206			
Year	**Population**	**Gr. %**	**CAGR (5 yr. intervals)**
2010	4259		
2015	4490	5.4%	1.1%
2020	4618	2.9%	0.6%
2025	4617	0.0%	0.0%
2030	4617	0.0%	0.0%
2035	4617	0.0%	0.0%
2040	4617	0.0%	0.0%
2045	4617	0.0%	0.0%
2050	4617	0.0%	0.0%
Source: \c NYMTC			

The injury rate was sourced from a *Centers for Disease Control* (CDC) report released post-Superstorm Sandy. This study entitled *Nonfatal Injuries 1 Week after Hurricane Sandy — New York City Metropolitan Area, October 2012* examined reported injuries one week after Sandy, by area (CDC, 2014). The study found that of the at-risk population, 10.4% sustained an injury in the first week after Sandy (CDC, 2014). **Table 14** shows the data that was applied to calculate a base year number of likely injuries sustained.

Table 14: Data Applied to Estimate Non-fatal injuries		
Parameter	**Value**	**Note**
Estimated At Risk Population	730	
Injury Rate:	10.4%	\a sustained an injury within first week after Sandy
Percent with 2 or more injuries:	70%	\a
Average injuries per person (for the 70%)	3.1	" "
Base Pop. level estimated no. of injuries:	75.87	Estimate from at Risk Population
70 % population with est. 3.1 injuries	53	\a
Remaining population, assigned 1 injury	22.76	
Estimated total injuries	187	
Source: \a CDC. MMWR / October 24, 2014 / No. 42		

The injury rate was applied to the projected population at risk over the project evaluation period to calculate the expected number of non-fatal injuries adjusted by the number of multiple injuries sustained by 70% of the impacted population at risk. From Table 2 of the *CDC Study*, the severity of injuries reported were mostly arm cuts, leg cuts, hand cuts and back, leg and foot strains. These types of injuries were cross-referenced to the most likely Abbreviated Injury Scale (AIS) suggested for use under the HUD Guidance for Benefit Cost Analysis (HUD CDP 16-06). **Table 15** reproduces the AIS table below.

Table 15: Selected Sample of Injuries by the Abbreviated Injury Scale (AIS)		
AIS	**Injury Severity**	**Selected Injuries**
1	Minor	Superficial abrasion or laceration of skin; digit sprain; first-degree burn; head trauma with headache or dizziness (no other neurological signs).
2	Moderate	Major abrasion or laceration of skin; cerebral concussion (unconscious less than 15 minutes); finger or toe crush/amputation; closed pelvic fracture with or without dislocation.
3	Serious	Major nerve laceration; multiple rib fracture (but without flail chest); abdominal organ contusion; hand, foot, or arm crush/amputation.
4	Severe	Spleen rupture; leg crush; chest-wall perforation; cerebral concussion with other neurological signs (unconscious less than 24 hours).
5	Critical	Spinal cord injury (with cord transection); extensive second-or third degree burns; cerebral concussion with severe neurological signs (unconscious more than 24 hours).
6	Unsurvivable	Injuries, which although not fatal within the first 30 days after an accident ultimately result in death.
Source: HUD CPD-16-06		

The estimated injuries were therefore assigned as AIS 1 Minor given that they corresponded to AIS 1.

Estimating the Avoided Monetary Cost of Mortality and Injuries

To estimate the avoided monetary cost of projected deaths and injuries, the HUD Guidance Source, *Table 2-2: Relative Disutility Factors by Injury Severity Level, (for Use with 3% or 7% Discount Rates)* (HUD CPD-

16-06) was applied. The cumulative number of deaths and injuries were valued by applying the 2016 Dollar values to these injury estimates by year.

Table 16: Relative Disutility Factors by Injury Severity Level, (for Use with 3% or 7% Discount Rates)

AIS Code	Description of Injury	Fraction of VSL	2015 Dollar Value	2016 Dollar Value
AIS 1	Minor	0.003	$28,800	$29,287
AIS 2	Moderate	0.047	$451,200	$458,828
AIS 3	Serious	0.105	$1,008,000	$1,025,042
AIS 4	Severe	0.266	$2,553,600	$2,596,773
AIS 5	Critical	0.593	$5,692,800	$5,789,047
AIS 6	Unsurvivable/Fatal	1	$9,600,000	$9,762,305

Sources:
See HUD CPD-16-06, page 9. Note that the original table found within the HUD Guidance was updated per the table called "Relative Disutility Factors by Injury Severity Level, (for use with 3% or 7% Discount Rates) sourced from the FAA document, <<econ-value-section-2-tx-values.pdf>>
https://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/econ-value-section-2-tx-values.pdf

U.S. Department of Labor, Bureau of Labor Statistics, CPI

Combined annual values for both the projected avoided costs of mortality and the avoided cost of injuries were calculated in the final step of the valuation procedure. The projected annual values were then discounted to present values by applying the HUD BCA Guidance 7% discount rate (HUD CPD-16-06).

iv. Avoided Mental Health Treatment Costs

After Superstorm Sandy, researchers quantified the incidence of depression, anxiety and Post Traumatic Stress Disorder (PTSD) on the impacted populations in the New York metropolitan region. In a study titled, *The Impact of Hurricane Sandy on the Mental Health of New York Area Residents*, Schwartz et. al. (2015) applied multivariable logistic regression models to examine the relationships between Superstorm Sandy exposure and depression, anxiety, and post-traumatic stress syndrome (PTSD). The probable depression was reported in 33.4 percent of the participants and the probable anxiety in 46 percent, and PTSD in 21.1 percent. Increased exposure to Superstorm Sandy was associated with a greater likelihood of depression even after controlling for demographic factors known to increase susceptibility to mental health issues (Schwartz, et. al., 2015).

To quantify the monetary cost of the avoided mental health treatment for depression and anxiety, this BCA applies the results of the incidence rate for PTSD of 21 percent to the estimate of the exposed population calculated for the Tottenville, Staten Island area for the casualty estimate. From this depression-affected sub-set of area residents, the BCA then applied the updated total per person treatment cost for mental health care that is used by FEMA (FEMA, 2012). This mental health treatment cost value was then adjusted for the expected annual chances of the storm events modelled in the avoided property damages estimates.

v. Avoided Lost Productivity Costs

The BCA applied the established FEMA methodology to calculate the avoided lost productivity costs for the cohort that would most likely experience mental health problems, anxiety and depression calculated above. FEMA also published suggested lost productivity losses per worker per day in their supplementary guidance (FEMA, 2012). These values were escalated to current 2016 US$ values per HUD Guidance. To calculate the number of wage earners who would most likely be unproductive because of mental health problems and anxiety, the labor force participation rate of 62.7% was applied to the group of individuals estimated from the exposed population of the Project alignment area who would most likely experience PTSD and anxiety. This lost productivity avoided cost estimate value was then adjusted for (annualized) the expected annual chances of the storm events modelled in the avoided property damages estimates.

vi. Avoided Shore Erosion/Dune Reconstruction Costs

Shoreline erosion benefits were based on the cost of restoring and replacing the cubic yards of shoreline that would have been lost annually over the 50-year evaluation period under the Future without Project scenario. This measure is a way of estimating the economic value of lost land that would occur in the absence of the Project, without any interventions that arrest erosion. The Living Breakwaters Project would avoid these maintenance and restoration costs over time. Because of the increased interest in beach restoration and nourishment projects in the New York and New Jersey area, the demand and supply market balance for fill materials has led to higher premium prices (SCAPE Appendix D, 2016). From this perspective, the Project offers substantial economic benefits as the up-front investment costs would result in substantial periodic maintenance cost savings over the 50-year evaluation period.

The avoided cost estimate is based on the volume (cubic yards) of materials that would be replaced at various intervals over time. Under the Future Without project scenario, modelling results have indicated that the projected shoreline change with erosion would amount to 12,940 cubic yards per year over the 50-year Planning Horizon. The avoided total volume of sand placement from the Project was estimated to be 647,000 cubic yards. The cost per cubic yard ($101/cy) was sourced from the Opinion of Probable Cost analysis and reflects current local market conditions as described above. The Design team characterized this process based on historical erosion rates occurring over the period spanning 1978-2012**.** Without the project, this erosion is expected to occur over the entire shoreline affected by the Project, within a 5000 – 6000 linear foot range (Arcadis, December 9, 2016).

In addition, the Project area is susceptible to the ocean-like shoreline conditions of Staten Island under storm/erosion conditions due to the regional funnel/surge effect that makes it comparable to ocean environments in terms of storm-induced erosion. The New York Bight Apex always experiences abnormally high surge levels attributable to the right angle made by Long Island and New Jersey coastlines that significantly increases storm surge levels wherever a hurricane has made landfall in the New York Bight Apex (Coch 2015).

The estimates of shoreline restoration costs and nourishment project interventions (that would be avoided with Living Breakwaters) are supported by a review of case studies examined for the purposes of assessing the actual historic volumes of fill materials that would be mobilized (per project) for shoreline protection. These case studies were reviewed to get a sense of the volume of materials associated with actual projects in the New York coastal zone per linear foot of shore protection project. Select beach locations were available for the New York shoreline and they provided an indication of the volume of materials mobilized for these projects (BND, 2016).

Figure 4
Illustrative Shoreline Dynamics - Observed Historic Shoreline Change
1978- Spring 2012 (Pre-Sandy)

Source: Modeling Report. Arcadis

Figure 5

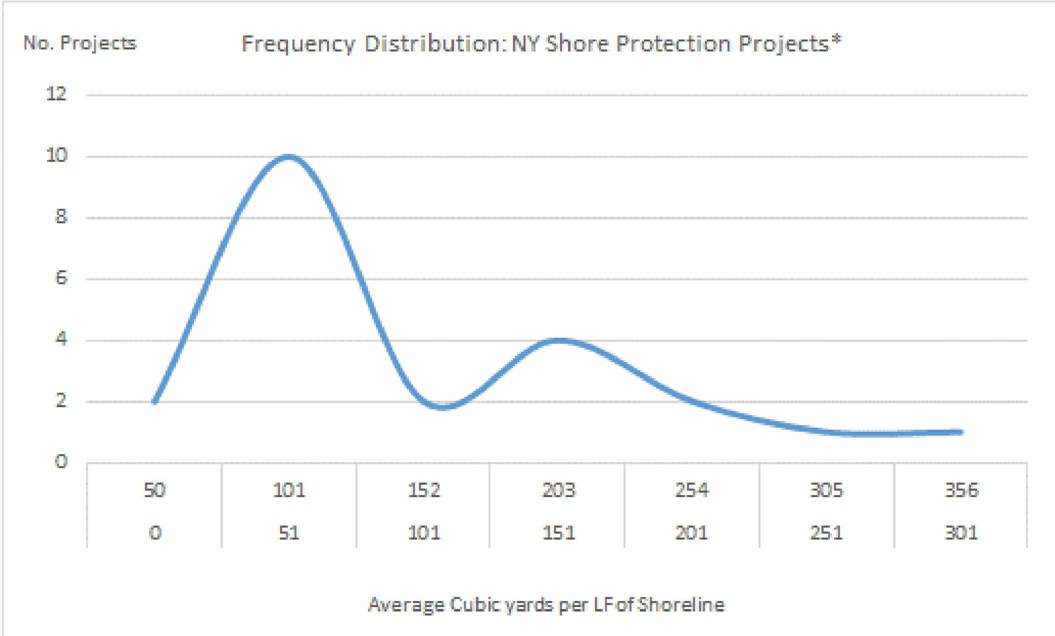
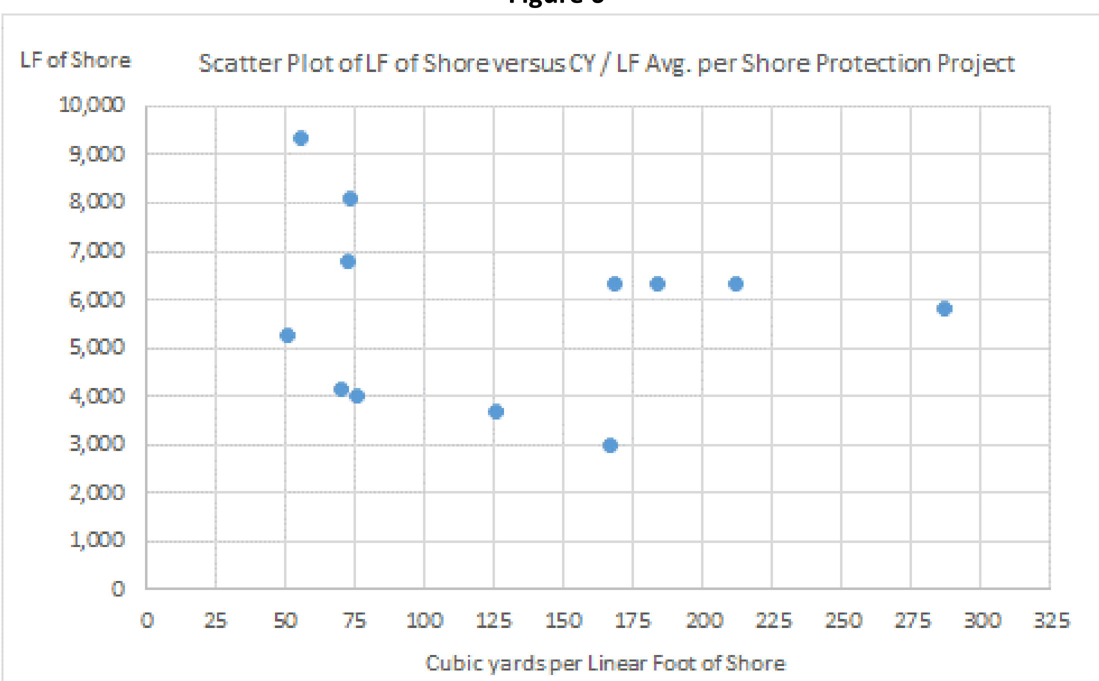


Figure 5 shows a bi-modal distribution of projects and the average volumes of material per linear foot (LF) of shore. At least 10 projects show fill volumes between 51-101 cubic yards per LF of shoreline protected. A scatter plot was also prepared for shorelines that were close in length to the Project alignment area. **Figure 6** shows the scatter plot of LF of shore protection projects versus the cubic yards per LF of materials mobilized. Projects with shore lengths between 4,000 and 7,000 LF were characterized by CY/LF amounts of between 50 and 75 cubic yards/LF.

Figure 6



This above data was referenced to inform and simulate the likely size of shoreline nourishment events (projects), given the total volumes estimated from the modelling exercise.

The avoided cost estimate was based on replacing fill along the shoreline erosion area at periodic intervals (every four years), as well as periodically reconstructing the dune based on a dune reconstruction cost estimate provided by NYC Department of Parks & Recreation (NYC Parks, 12/12/16). In addition, the BCA also simulates a total dune replacement construction cost that would occur two times over the project evaluation horizon of 50 years. This latter cost was also sourced from NYC Parks and was escalated to 2016 dollars from the original 2013 dollar cost (NYC Parks, 01/03/17).

It was assumed that without the Project sustained erosion would continue, punctuated by storms (and their impacts). For purposes of Benefit Cost Analysis, it was assumed that – absent the Project - this would require more frequent reconstruction efforts every few years. The BCA addresses the value of land that would be lost "but for" the Living Breakwaters Project. The avoided cost of shoreline nourishment and dune reconstruction addresses this value over time because it is linked to rates of erosion.

To address the value of eroded shoreline, unit costs for replacement fill were also sourced from the Opinion of Probable Cost for the Project's 30 Percent Design Report document and applied in the estimates. The cost per cubic yard of fill for shoreline restoration (source, transport, and load/install sand) was applied as derived from the 30 Percent Design Report Opinion of Probable Costs. These unit costs were applied to the volumes of shoreline that would be eroded over time without the project.

vii. Avoided Road Closure/Travel Disruption costs

Superstorm Sandy resulted in substantial travel time delays for commuters due to closed roads, poor road conditions and damages sustained from debris carried onto roads from wave surges and strong winds (PlaNYC, 2013). Following Sandy, commuters who did not have the option to telecommute experienced increased frustration levels and substantial increases in commute times from traffic congestion and detours, with commute times sometimes spanning two to three times as long as their normal pre-Sandy daily commute. Since Staten Island is geographically separated from the major centers of employment in Manhattan, the frustration levels (measured by an index out of 10, with 10 being the highest) were relatively high (7 out of 10). For Staten Island residents the average pre-Sandy commute time was 84 minutes. The average post-Sandy commute time (Nov. 1-2) was 240 minutes (Kaufman et. al. 2012).

The BCA applies the FEMA methodology to value the cost of avoided road closures based on the value of time. This method recognizes that individuals who experience increased travel time due to bridge or road closures attach an economic value to the lost time incurred (FEMA, 2011).

To value the avoided travel time delays associated with avoided road closures and disruptions, the working age population was estimated from the Traffic Analysis Zone (TAZ, 2206) population for the Tottenville shoreline community based on the labor force participation rate. It was assumed that an average two-hour delay would be incurred over a two-week period for this group of estimated commuters. The value per hour applied ($33.5/ hour, 2016) was updated from FEMA's guidance value for 2011 based on applying the Consumer Price Index. The resulting travel time disruption value was then converted to an Expected Annual Damages amount. The Expected Annual Damages amount was based on the 1% chance annual storm event factor for the 100-year design event per the Project assumptions noted in the appendix.

viii. **Avoided Cost of Power Outages**

Power outages caused considerable disruptions following Sandy. It has been estimated that 120,000 customers lost power on Staten Island, and repairing damage to the aboveground electrical power network took approximately two weeks (PlaNYC, 2013).

The BCA applies the FEMA method to value power outages under the 100-year design storm event (FEMA, 2011). Application of the FEMA method involved first estimating the functional downtime (measured as the system days of lost service). Using this approach, a two-week functional electrical service disruption estimate was assumed for the Tottenville community under a 100-year design storm event. This corresponds to the likely impacts from a 100-year storm event. The population for the Traffic Analysis Zone (TAZ 2206) applicable to the study area was used as a proxy for the number of people served by the electric power utility. The economic impacts of lost electric power service was then calculated using the per capita economic impacts and the affected population. FEMA has developed per capita values to calculate the economic impacts, and these values were updated to 2016. **Table 17a** shows the value applied in the BCA.

Table 17a: Economic Impacts of Loss of Electric Power (per capita per day)

Category	Economic Impact (2010 dollars)	Economic Impact (2016 dollars)
Impact on Economic Activity	$106	$118
Impact on Residential Customers	$25	$27
Total Economic Impact	$131	$145

Source: FEMA 2011

The resulting avoided annual cost of lost power was then converted to an Expected Annual Damages amount based on the 1% chance annual storm event factor for the 100-year design event.

ix. Avoided Cost of Damaged Vehicles

Inundation would damage motor vehicles—including cars, small trucks, and heavy-duty trucks. The damaged incurred to vehicles depends on the vehicle type. Automobiles, which are closer to the ground than small trucks or heavy-duty trucks, are more susceptible to water damage than larger vehicles.

In the study area, vehicles parked at residences are at risk. However, unlike other assets, motor vehicles could be moved away from potential inundation zones, avoiding damage from inundation. The number of vehicles within the study area was determined using the Hazus Daytime Vehicle Inventory. In this database, vehicle distributions within a census block are estimated based on the occupancy-type of each census block. The database also includes the total value of vehicles susceptible to inundation in each census block.

The damage to vehicles was calculated as a portion of the total value of vehicles in a census block. First, the number of vehicles affected by inundation was estimated by applying the percentage of inundation buildings in a census block to the total valuation of vehicles in a census block. For example, if 40% of buildings within a census block were affected by inundation, 40% of the vehicle valuation in a census block was estimated to be affected by inundation. Next, depth damage functions for vehicles were used to estimate the damages as a function of the value of affected vehicle valuations. For example, if 10% of the inundation area had a depth of 1 feet, then the damages to vehicles at that flood depth was estimated as 15% of the vehicle valuation.

Using this methodology for both Future with and Future without scenarios, the mitigated damages to vehicles for various storm events were calculated. The results are shown in **Table 17b** below. As stated in the previous sections, the mitigated damages were estimated for today's 100-year storm event and for the 50-year and 100-year storm events with 30" sea level rise. For all other storm events, the existing dune would provide sufficient wave attenuation to prevent wave damage to buildings, even without the breakwaters.

Table 17b: Mitigated damages to vehicles

Storm Event	Vehicle Damages under Build Scenario	Vehicle Damages under No Build Scenario	Difference (Mitigated Damages, per event)
Today 100 Year	$ 2,309,557.68	$ 2,309,557.68	$0.00
SLR 50 Year	$ 2,501,928.67	$ 3,321,572.61	$819,643.94
SLR 100 Year	$ 3,473,547.91	$ 4,441,396.94	$967,849.03

The mitigated event based damages were converted to Expected Annual Damages (EAD) in the benefit cost analysis by applying Equation 1 above.

c. Environmental Value

The environmental value of the Project was estimated through the evaluation of ecosystem service provisioning provided by the Project and subtracting negative effects of the Project on ecosystem services. The ecosystem services for the Project were derived from a combination of the estimated habitat area (in sq. ft./acres), and from habitat values per acre obtained from published literature sources (Grabowski et al, 2012). The SCAPE team provided the estimates of the habitat sizes in acres for the Project that would be both gained and displaced. The ecosystems services valuation for the BCA is limited to the value of net acres gained by ecological service type.

Table 18 below shows the ecosystem service types valued and the original values per hectare per year. The HUD BCA Guidelines (HUD CPD-16-06) guidance on escalating prior year values to 2016 constant dollars was applied to update the original value estimates to 2016 values.

Changes in the intertidal and subtidal habitat areas related to shoreline restoration activities were not addressed since the net change in area is insignificant and thus a change in ecosystem service value would not be appreciable.

Table 18: Summary of Ecosystem Services Applied to the Proposed Living Breakwaters/Oyster Reef Project

Service Type	Measurement	Average Value/hectare /year	Original Date of Valuation
Oyster habitat/reef sustainability	density (ind./m^{-2})	\$ 880	2011
Production Augmentation Finfish and Crustaceans-			
Commercial	\$4.12 / $10m^{-2}$ of reef area	\$ 4,123	2011
Shoreline Stabilization	10% reef stabilizes shoreline	\$ 8,600	2011
Water quality			
Nitrogen removal	246 micromoles/h^{-1}/m^{-22} of reef below MHW occupied by filter feeders	\$ 4,050	2011
SAV enhancement	1 ha reef = 0.0 05ha SAV	\$ 1,292	2011

i. Total Gross Ecosystem Annual Service Gains (+)

Ecosystem services annual gains were assessed for the proposed ecologically enhanced breakwater system and oyster restoration using the services of habitat/reef sustainability, commercial finfish, water quality, habitat and recreation. Monetary values are derived from Grabowski et al (2012), Costanza et. al. (2006) and Kaval and Loomis (2003). The monetary values from the literature were adjusted to 2016 values using the U.S. Bureau of Labor Statistics CPI index (**Table 19**). The estimated square feet of each habitat type was derived from the calculations provided by the design team in a December 13, 2016 memorandum entitled *Calculation of Available Surface Area and Marine Habitat Generated for Living Breakwaters* (SCAPE, December 13, 2016). The design team estimated that approximately 70% percent of the total accessible surface area (ASA) of the structure would be below the mean high water tide elevation (MHW) and suitable for marine organism colonization and use. Since this area below MHW would be a complex area with niches and crevices inhabitable by fish and other benthic species, the actual surface area of usable habitat created would be substantially greater than the planar surface area of the structures. In addition, a subset of this area, approximately 40 percent, was assumed available for oyster establishment during the initial maintenance period. These factors were applied to adjust the available surface area of the structures that have the potential to provide ecosystem services.

Table 19. Summary of 2016 annual ecosystem service values for the breakwater/oyster reef system.

Breakwater / Oyster Reef				
Service Type	**Accessible Surface Area[1] (square feet)**	**Planar Reef Area (square feet)**	**Acres**	**2016 Average Value / acre / year**
Oyster habitat/reef sustainability	753375		17.3	$2,336.84
Finfish and Crustaceans				
Commercial	1884437		43.3	$10,948.62
Water Quality				
Nitrogen removal	1507550		34.6	$10,754.77
SAV enhancement		553212	12.7	$14,177.33
Habitat				
Refugia	1884437		43.3	$435.78
Recreation (diving)	NA	NA	1[2]	$9077.50

Notes: 1 – ASA is the area of reef below mean high water elevation.
2 – Recreation service is based on a single reef system.

To account for a lag time in the establishment of reef habitat and benefits, percentages (out of 100% of full annual ecosystem service delivery) are applied to specific services during the first three years post-construction. **Table 20** lists the modifiers used in this analysis. The values applied are based on references reporting on monitoring observations for constructed reefs and breakwaters.

Table 20: Ecosystem Habitat Extended Value/Time Lag Modifiers			
Breakwater/Oyster Reef	Extended Value / Time Lag Modifiers		
Service Type	Year 1	Year 2	Year 3
Oyster habitat / reef sustainability	0.50	0.75	1.0
Finfish and Crustaceans			
Commercial	0.90	1.0	1.0
Water Quality			
Nitrogen removal	0.50	0.75	1.0
SAV enhancement	0.50	0.75	1.0
Habitat			
Refugia	0.9	1	1
Recreation (diving)	1	1	1

ii. Total Ecosystem Annual Services Displaced (-)

The construction of the breakwaters would displace approximately 12.7 acres of subtidal small and large grained bottom habitat. For Sub-tidal sandy bottom, service areas and monetary values were derived from Costanza et al (2004) and include water supply, biological control, nutrient regulation, and cultural and spiritual values. Costanza (2004) referred to the subtidal coastal zones as "Coastal Shelf" which was defined as the subtidal zone below the beach elevation.

Table 21: Summary of Ecosystem Services Applied to the Displaced Subtidal Habitat: Subtidal small and large grained bottom habitat			
Service Type	Measurement	Avg. Value /acre /year	Date
Water supply	acre/year	$ 521	2004
Biological Control	acre/year	$ 20	2004
Nutrient Regulation	acre/year	$ 723	2004

iii. Net Ecosystem Annual Service Gains (-)

The total calculated value for the displaced subtidal habitat was subtracted or netted from the breakwater/oyster reef total values. The net annual per acre value of the combined ecosystem service values for Breakwater/Oyster Reef habitat is $36,123 after three years post-construction based on an estimated 43.3 acres of habitat. The cumulative NPV from 2016 to 2066 is $11,596,212.

There is some uncertainty associated with the source of the ecosystem service values and their direct application to the New Ecosystem Annual Service Gains, which may experience lower oyster densities and growth rates of filter feeders, and the ability of the breakwater/oyster reef in achieving full functionality.

To account for this uncertainty, a three-year lag time for some services was built into annual valuation based on literature sources (La Peyre et al, 2013).

To better visualize the types of ecosystem services that will be supported by the Project in the future, **Figure 7** is reproduced below.

Figure 7: Schematic of Living Breakwaters Underwater View

Source: SCAPE Press packet images.

d. Social Value

To estimate the social values that would arise from the Project, a combination of comparable usage at similar educational and environmental stewardship facilities and area park recreational visitation patterns was combined with benefits transfer. Benefits transfer is the process of adapting an existing value estimate (such as the willingness to pay for an amenity or park service) and transferring it to a new application that is in another location and may be similar, but is different from the original one. There are two types of benefit transfers, value transfers and function transfers. A value transfer takes a single point estimate or an average of point estimates from multiple studies, to transfer to a new policy application. A function transfers uses an estimated equation to predict a customized value for a new policy application. Social values for the Project were estimated by applying a “value” transfer to the unit values applied, that represent the willingness to pay for recreational and specific type of environmental education among potential users.

i. Education and Environmental Stewardship

The project will provide educational opportunities for area residents and recreational users, through the application of environmental and stewardship programs, and the use of the on-shore community water hub. It is anticipated that most educational users would be area residents from the immediate area and lesser so from the region, as well as nearby school systems. The water hub itself will in part be geared towards education, with classrooms and learning facilities that will make environmental education possible year-round. All proposed water hub design concepts incorporate these types of educational program possibilities. The water hub will be particularly relevant for education during late fall and winter, and early spring, when outdoor activities are limited. The augmentation of the beach and surrounding open areas by the Living Breakwaters Project will provide enhanced outdoor educational opportunities as well. The Project offers a unique opportunity for marine based education within an urban setting.

The community water hub has the advantage of not competing with other types of facilities offering similar amenities because it offers local and regional residents (clustered around Raritan Bay) a unique opportunity. From this perspective, the potential for capturing specific types of visitors and the potential for sustained growth over time is possible if it does not interfere with the activities of permanent residents and homeowners in the Project area.

Education in a recreational and outdoor setting is typically geared towards specific extracurricular environmental activities, and is considered a measurable aspect of recreation. It was determined that the educational benefits associated with the Project represented a quantifiable value. To determine the overall education value, a per-visit utility value was applied. This visitor utility value was based on the results of a per visitor value obtained from a study conducted by Texas A&M University (Harnik and Crompton, 2014). This figure was applied to an estimate of the total persons per year who would be availing themselves of educational opportunities at the Project including the water hub and associated programming, which was derived from NYC Department of Parks and Recreation figures provided by the GOSR, to arrive at an estimated annual benefit for the project.

Based on this methodology, the cumulative present value of these benefits was estimated to be $1,253,995.

ii. Recreation

The completion of the project will enhance recreation opportunities along the shoreline as well as just offshore. The addition of the community water hub will allow waterfront access and a place where kayaks can be launched and stored. The additional beach area (beach width) and calmer waters resulting from the breakwaters will provide opportunities for the community to fish, view the waterfront, boat, and perform other beach and water activities. These recreational opportunities represent a tangible direct use benefit that the Project would provide. It is anticipated that the majority of recreational users will be local area residents and some residents from the greater region.

Several approaches were considered for obtaining an estimated recreational benefit value, including applying a value per acre value as well as a per visit utility figure. An approach using a value per visit utility figure was used, as obtainable data supported this approach best. To obtain an estimated value, three separate per-visit utility values were applied: one for walking, hiking, biking, and fishing (these activities all had the same utility within the primary study utilized). Kayaking was assigned the boating value. These value estimates were sourced from a study conducted by Texas A&M University (Harnik and Crompton, 2014). In addition, an estimate of the overall annual visitation was derived using visitation figures from a nearby State park, Clay Pit Ponds State Park Preserve on Staten Island (CPPSP, 2016).[2]

The percent of annual visitors that would engage in each activity was estimated in **Table 22** below.

Table 22: Recreational Users Breakout	
Type of Recreation	Percent of Annual Visitors
Walking, hiking, biking, and fishing	70%
Kayaking	20%
Boating	10%

The per-visit utility figure was applied to each estimated number of recreation users to arrive at an estimated annual benefit for each type of recreation. These were then added together to arrive at a total annual figure for all recreation. Other types of recreation may occur at the Project site, such as seashell collecting or bird watching. As utility figures for such activities would be quite difficult to find, and considering these types of activities could be grouped as walking or hiking, it is assumed such activities fall into the categories for walking and hiking.

Given the novel feature that the Living Breakwaters will represent to local boating enthusiasts, additional research was conducted on the number of small boat slips at marinas on Staten Island that could access the Project. From the total number of slips, an estimate of potential visitation associated with these small boats was completed. The number of potential visitors who would likely visit the Project area by small boat was then valued by applying the above per visit utility figure. **Table 23** shows the estimate of marina slip capacity.

Table 23: Staten Island Marinas	
Name	Slip Capacity
Atlantis Marina	170
Captains Marine Mercury	160
Great Kills Yacht club	250
Mansion Marina	217

[2] Clay Pit Ponds State Park Preserve is a 265-acre nature preserve near the southwest shore of Staten Island. It contains a variety of unique habitats, such as wetlands, ponds, sand barrens, spring-fed streams and woodlands. The preserve is managed to retain its unique ecology and to provide educational and recreational opportunities for people of all ages. Educational programs, such as nature walks, pond ecology, birdwatching and tree and flower identification, are offered, as are many activities geared to school children. The Preserve also has an Interpretive Center that is a fully accessible building featuring interpretive displays of the history of the park and of its natural elements. The Park's educational and community programs are offered at the interpretive center.

Table 23: Staten Island Marinas	
Name	Slip Capacity
Marina Café	270
Nichols Great Kills Marine	350
Port Atlantic Marina	240
Richmond County Yacht Club	40
Staten Island Yacht Sales	50
Tottenville Marina	240
Unnamed Marina	166
\a Estimated Total:	2153

Note: \a Select marina capacities were estimated from aerial photographs.
Source:
http://marinas.com/search/?search=1&category=marina&country=US&region=NY&city=Staten+Island

The estimate of small boat total visitors was based on assuming a boat party size of three persons. It was assumed that two-thirds of the slip capacity boats would visit the Project area three times over the course of a year. Based on these assumptions, approximately 13,000 annual boat trips could be generated from the available marine slip capacities estimated.

The cumulative present value of recreation benefits was estimated to be $7,095,681 over the fifty-year period.

iii. Community Cohesion

Parks and beaches offer an opportunity for community members to meet, interact, strengthen the community and build social capital. Several studies on the value of parks and open space include community cohesion as one of the benefits of parks (NPRA, 2010, and Harnik, 2014). In neighborhood parks, residents of all ages have the opportunity to interact, which improves the quality of life in the neighborhood. Furthermore, the social capital that is created through parks - especially when neighbors work together to create, save or renew a park or open space - not only benefits resident quality of life but wards off anti-social problems, reducing the need for police, prisons, and rehabilitation (Harnik, 2014).

The benefit of community cohesion was not quantified. The magnitude of the benefit will be affected by the level of community involvement during the planning and development of the project as well as by the use of the project area and facilities by residents upon the project's completion.

iv. Workforce Development

The Project includes a workforce development program for which the details still have to be developed. It is expected that the program will train participants prior to the construction period (e.g., skills such as welding), during construction and during operations (e.g., marine education skills). Children of participants in the workforce development program are expected to benefit from their parents' employment beyond the value of increased wages and benefits (Ridley 2011). Examples include improved academic achievement, health improvements and improved workforce prospects (Magnuson 2007). Studies show that when mothers with low education levels complete additional education, their children appear to have improved language and reading skills (Magnuson 2009).

The social value impact of the workforce development programs on families who would benefit from the Project was not quantified. The magnitude of the benefit will depend on the number of participants with families and the prior education and income levels of participants, however, there is a community benefit to performing this service.

The program objectives will allow students from disadvantaged, minority and low-income communities to attend educational events and enjoy trips to the water hub, and Project area. The goals of the program are to provide these educational and environmental stewardship services to public schools who could arrange for trips to the Project area. Therefore, the water hub and associated programming activities provides an outlet for these students from all walks of life who attend schools within the NY Metro area. This proximity will result in greater access and exposure to the resilient environmental and community asset.

e. Economic Revitalization

Economic revitalization benefits will arise from the Project's short-term construction phase impacts on jobs, earnings and regional output, and will accrue to local adjacent property owners from anticipated positive property value impacts beyond those provided by the coastal risk reduction function of the Project.

i. Economic Impacts

Job Creation

During the construction phase, the project will support jobs in construction and related industries. Upon its completion, the project will support jobs related to the O&M of the community water hub and programming activities, breakwater, oyster restoration efforts and beach. While typically not a net benefit to society, job creation constitutes a positive contribution to the New York City and New York State economies. Due to the unique character of the Project, it may attract local and out-of-state visitors whose spending would further increase the economic contribution of the Project to the New York City and State economy, respectively.

Construction Phase

An analysis performed by AKRF as part of the Draft Environmental Impact Statement (DEIS) for the Project found that the construction of the Project (Alternative 3 in DEIS) would support a total of direct jobs, equivalent to 282 person-years[3] of employment in the construction and related industries. Considering the indirect and induced jobs that would be generated through the multiplier effect, the Project would support an additional 129 person-years of employment in New York City and an additional 8 person-years of employment in the rest of New York State.

The estimate is based on a cost of approximately $66.5 million in 2016 dollars, which includes all hard costs for the Living Breakwaters Project but excludes contingency costs.

Operation and Maintenance Expenditures

O&M expenditures of the community water hub would include utilities (energy, water, and solid waste), programming expenditures including programming staff, and building maintenance expenditures, which would also include staff. In addition, O&M expenditures would arise from breakwaters and oyster reef annual sustainment. In addition, monitoring activities would also generate annual spending impacts to the region. The BCA referenced the Alley Pond Environmental Center Inc. (APEC), located in Queens, as an example of an organization with a similar related mission of environmental education and stewardship, as a frame of reference for a portion of the Project's O&M. APEC is a non-profit organization dedicated to educating children and adults in the New York metropolitan area, protecting and preserving Alley Pond Park, open spaces and water bodies, and advocating for sustainable environmental policies and practices.[4] Based on the APEC 2014-15 Annual Report, a total of 45,239 children and 17,570 adults were served by APEC's education programs. The operating expenditures of the APEC in the fiscal year 2014-2015 were $910,000 of which $550,000 was used for employee compensation and building utilities and sustainment.[5] While not entirely comparable, these values do provide an indication of the type of annual spending impact in terms of the relative magnitude of dollars per year that would be indicative of a similar range for the Project. These annually recurring expenditures would also generate direct, indirect and induced economic impacts within the community and region.

Visitors (not quantified)

Should the Living Breakwater Project attract visitors from outside New York City, or outside New York State, spending by these visitors (i.e., food, retail, transportation, and other recreation) would generate a positive impact on the New York City and New York State economies. For example, it can be expected that a portion of the visitors attending the family and adult education programs and/or persons traveling to the area for recreational purposes (e.g., kayaking) may reside outside of New York City, especially from neighboring New Jersey. The potential impact of visitor spending was not quantified due to the difficultly of anticipating the number of regional visitors but it is expected to add some value in the future.

Increased Earnings and Benefits

The Project includes a workforce development program for which the details have not been developed. It is expected that the program will train participants prior to the construction period (e.g., skills such as

[3] A person-year of employment is the equivalent of one person working full-time for one-year.
[4] Alley Pond Environmental Center, 2014-2015 Annual Report
[5] Alley Pond Environmental Center, 2014-2015 Financial Statements

welding), during construction and during operations (e.g., marine education skills/operations). After completing the training, participants in this program may benefit from a lifetime increase in earnings, which would represent a long-term benefit of the project.

ii. Property Value Impacts

Economists have applied hedonic property price based statistical (regression based) methods to isolate the effects of various attributes or amenities that can influence property values. Hedonic methods analyze how the different characteristics of a marketed good, including environmental quality, might affect the price people pay for the good or factor. This type of analysis provides estimates of the implicit prices paid for each characteristic, such as the number of rooms, and the quality of the adjacent host environment. A hedonic price function for residential property sales might decompose sale prices into implicit prices for the characteristics of the lot (e.g., acreage), characteristics of the house (e.g., structural attributes such as square footage of living area), and neighborhood and environmental quality characteristics. In terms of aquatic ecosystems, properties with closer proximity to these systems may sell for more than similar properties that do not have this adjacency or proximity (NRC, 2005).

The hedonic analysis method is a statistical procedure for accounting for, and disentangling estimates of the market price premium that residents pay for ocean frontage or having access to higher quality recreational amenities and ecological services. The BCA applied a hedonic market study that quantified the market value property value premium associated with the width of the beach itself. This study was particularly relevant to the Project's objectives of arresting beach erosion and providing for a contiguous beachfront and improved utility and access along the Project alignment.

The BCA applied a particular study that examined the increase in residential property values associated with a one-foot increase in beach width (Gopalakrishnam et. al, 2010). The study included a functional determination or elasticity of (distance to x beach width) with respect to home prices. According to the study, a one-foot increase in beach width was associated with a 0.5% increase in home prices for those homes located within 32.8 feet from the LiMWA. To apply the results of this study through benefits transfer techniques, the BCA used GIS to isolate those homes within the Project area that were within 10 meters (32.8 feet) from the Limits of Moderate Wave Action (LiMWA).

For the parcels located within 32.8 feet from the LiMWA, the cumulative present value of the beach width premium portion of the property value increase amounted to $2,953,868 over the period spanning from 2016-2066 (a 50 year period). This market premium was based on holding the current market value of these properties constant in 2016 dollars as per HUD BCA Guidance (HUD CPD-16-06).

IX. Project Risks

a. Description of Project Risks

Project risks generally relate to issues that could influence both the cost and timing of construction (SCAPE Appendix D, 2016), as follows:

- **Ecological Limitations on Construction Periods** - The winter flounder spawning season typically spans from January to May, while the horseshoe crab spawning season can potentially impact the project from Mid-April to Mid-August. Flounder and horseshoe crab mating seasons have the potential to lengthen the Project construction phase as construction activities could be suspended during the spawning seasons thereby extending the needed timeframe for construction. The BCA incorporates these restrictions to the construction timeline. For the BCA, a 19-month construction schedule was applied instead of a 14-15 month construction schedule.

- **Availability of Construction Materials** - Other factors relate to sourcing and availability of raw materials used in construction. This risk relates to contracting with the lowest cost suppliers of stones in sufficient quantities, with the appropriate rock sizes and qualities, having the needed surface textures to support and grow habitats. In addition, there is some risk related to sourcing sand quantities that meet quality and suitability criteria for shoreline restoration. Given high demand for beach nourishment fill in the New York/New Jersey region unit prices may be higher for these materials that could influence Project construction costs.

- **Localized Unfavorable Construction Conditions** - In addition, some project aspects could influence the estimated construction costs such as unanticipated soft soils/sediments that may be encountered in certain locations. These soils could lead to remedial procedures that could raise costs.

- **Extreme Weather Conditions** - The storm/hurricane season in New York has the potential to influence the construction schedule.

- **Stakeholder Concerns** - Other risks relate to the possibility that certain stakeholders have concerns about the Project that could affect its construction schedule and cost. It is noted that the Design Team has performed informative outreach activities, and will continue to perform these activities, to inform stakeholders about the goals, objectives and benefits of the Living Breakwaters Project and get regular feedback from stakeholders throughout the design process.

b. Sensitivity Analysis

A sensitivity analysis was completed that assessed the impacts on the Project's cumulative present value of net benefits and BCRs of potential increases in Project costs and reductions in anticipated Project benefits for the categories providing the most value (and thus most likely to affect the BCR and NPV). **Table 24** shows the results of the sensitivity analysis.

Table 24: BCA Sensitivity Analysis

Test	Baseline Project Net Present Value / BCR	Project Net Present Value with Change	BCR with Change	Switching Value \a
[1]	[2]	[3]	[4]	[5]
Increase in Capital Costs (30%)	$13,654,244 / 1.22	-$2,818,743	0.96	24.867%
Increase in Annual O&M (50%)	$13,654,244 / 1.22	$10,114,140	1.15	192.9%
Decrease in Resiliency Benefits (Percent of Baseline Estimates):				74.33%
90% of Baseline	$13,654,244 / 1.22	$8,334,438	1.13	
80% of Baseline	$13,654,244 / 1.22	$3,014,632	1.05	
70% of Baseline	$13,654,244 / 1.22	-$2,305,174	0.96	
Decrease in Environmental Values (Percent of Baseline Estimates)::				
90% of Baseline	$13,654,244 / 1.22	$12,491,148	1.20	
80% of Baseline	$13,654,244 / 1.22	$11,328,053	1.18	
70% of Baseline	$13,654,244 / 1.22	$10,164,958	1.16	
60% of Baseline	$13,654,244 / 1.22	$9,001,862	1.14	
50% of Baseline	$13,654,244 / 1.22	$7,838,767	1.13	
0% of Baseline	$13,654,244 / 1.22	$2,023,290	1.03	

Notes:
\a The switching value is the value that renders the cumulative net present value of the Project equal to zero, (B=C, BCR=1.0), holding all of the other variables constant.

Column [1] shows the type of stress test the BCR and present value of net benefits (NPV) were subjected to. A thirty percent increase in capital costs would lower the BCR from 1.22 to 0.96, and erase the positive cumulative net present value of the Project. The Switching Value shows the increase in capital costs that would render the net present value of the Project equal to zero. A fifty percent increase in annual O&M would lower the baseline BCR from 1.22 to 1.15, holding all other variables constant.

Resiliency and environmental values provide the majority of the benefits for the Project. The sensitivity analysis starts by reducing the combined value of resiliency benefits to a percentage of the baseline total values. The Project's total net present value would still be positive even if resiliency benefits fell to 80 percent of their current estimated level. The switching value for combined resiliency benefits is 74.3 percent of the baseline level.

Discount Rate

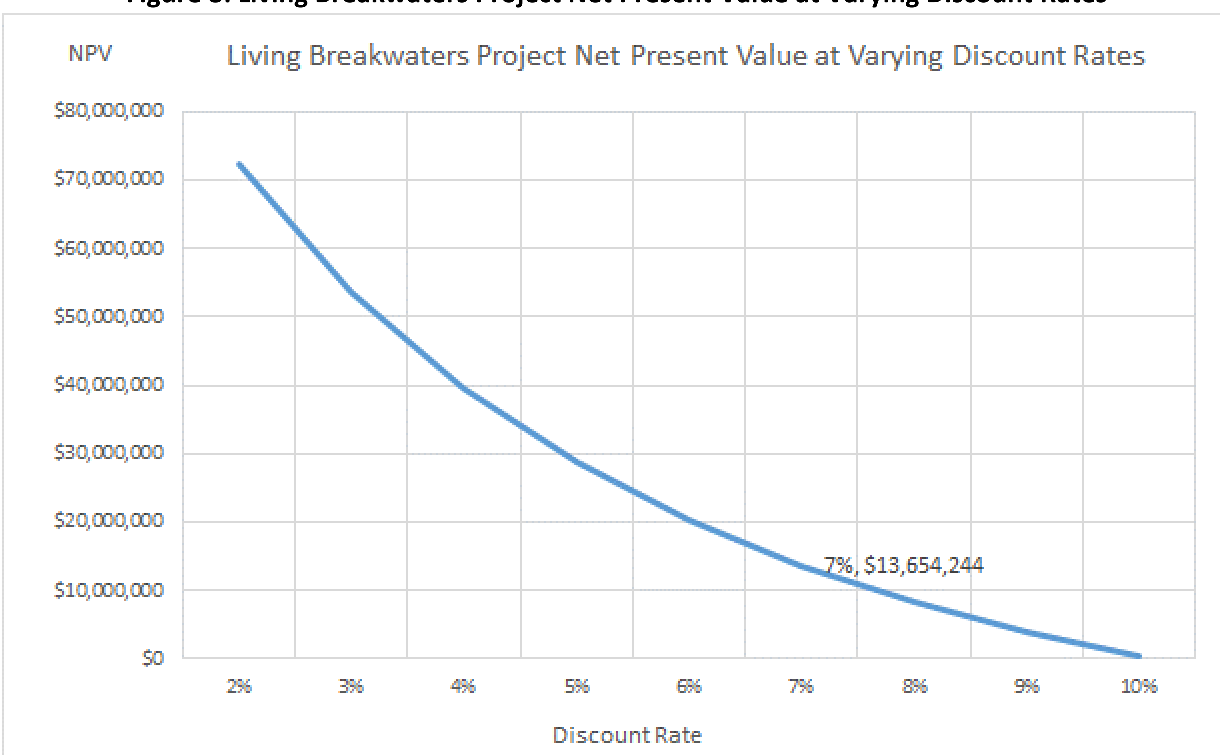
The sensitivity of the Project's NPV and BCR was also assessed for changes in the discount rate. **Table 25** shows the Project's cumulative present value of net benefits and BCRs at various discount rates. The Project's NPV and BCR remain favorable at discount rates up to 9%. This means that if we were to assign greater risks (stressors) to the net benefits being realized over the 50-year period, the Project would still add value to the community.

Table 25: NPV and BCRs at Varying Discount Rates

Discount Rate	NPV	BCR
2%	$72,215,629	1.88
3%	$53,588,954	1.70
4%	$39,534,477	1.55
5%	$28,743,575	1.42
6%	$20,323,018	1.31
7%	$13,654,244	1.22
8%	$8,302,480	1.14
9%	$3,957,455	1.07
10%	$394,305	1.01

Figure 8 plots the results of the sensitivity analysis of the Project's net present value at various discount rates.

Figure 8: Living Breakwaters Project Net Present Value at Varying Discount Rates



X. Assessment of Implementation Challenges

As outlined in the description of the Project risks noted above, the Project faces some implementation challenges. These challenges relate to coping with unforeseen factors that can affect construction costs and unanticipated delays in the construction schedule, and other uncertainties associated with offshore coastal construction and permitting. In addition, some challenges relate to effectively explaining the Project benefits to select constituencies and the overall community.

However, the sponsor and design team are effectively addressing these challenges in pro-active and engaging ways that are reducing the risk to successful implementation of the Project. A variety of public outreach and informational meetings have been scheduled, including the creation of a Citizen's Advisory Committee to allow stakeholders to advise GOSR on design concerns and ultimately construction impacts. These activities will continue to be hosted and promoted in the future.

XI. Conclusion

This BCA for the Living Breakwaters Project was prepared by following the HUD BCA Guidance for APA for RBD Projects (HUD CPD-16-06). The analysis was completed using generally accepted economic and financial principles for BCA as articulated in OMB Circular A-94.

The Project is designed to 1) Reduce coastal risk through decreasing exposure to wave action and associated erosion along the shoreline in Tottenville, Staten Island; 2) Enhance habitat functions and values supporting local ecosystems through the creation and improvement of near shore and coastal habitat; and 3) Foster stewardship and recreational and educational use of the coast and nearshore through increased awareness, access, and participation.

Using a 7% discount rate, and a 50-year planning evaluation horizon, the Project will generate substantial net benefits to the shoreline community of Tottenville, Staten Island, New York, as well as other beneficiaries from the New York metropolitan region, and regional visitors who use this community asset. **Table 26** and **Figure 9** Living Breakwaters Project – Benefit Cost Analysis Summary provides more details on the categories of benefits and costs that were estimated.

To summarize, the lifecycle costs to build and operate the proposed Living Breakwaters Project investment (amounting to $62.4 million in constant 2016 present value dollars) would generate the following quantified benefits (and not including benefits discussed above but not quantified for various reasons):

- Total Benefits of $ 76.1 million, of which:
  - Total Resiliency Values are $53.2 million
  - Total Environmental Values are $11.6 million
  - Total Social Values are $ 8.3 million, and
  - Economic Revitalization Benefits are $2.95 million

The Project's cumulative present value of net benefits is **$13.7 million** and the **BCR is 1.22**. These measures of project merit demonstrate that the Project is viable and would add value to the community, the environment and the economy.

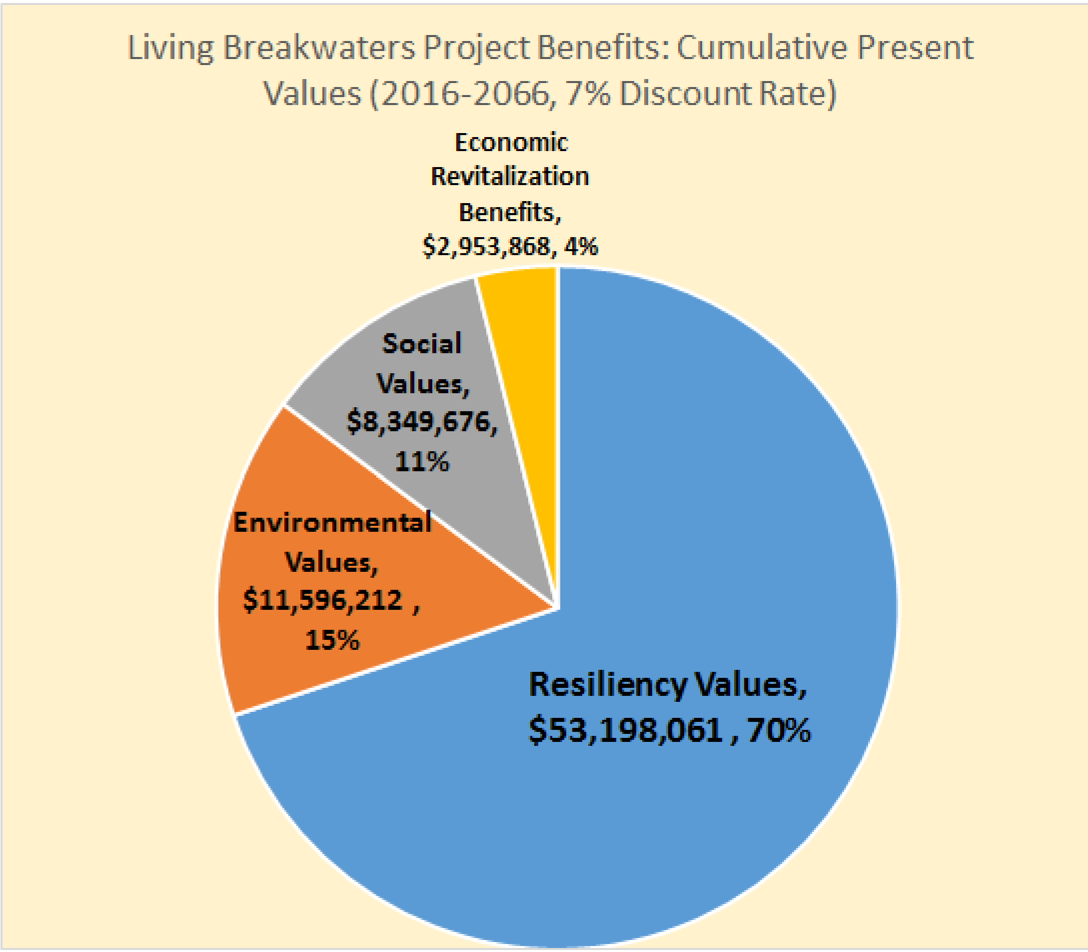
The Project's future annual benefit and cost streams, projected over the 50-year horizon, were also subjected to a sensitivity analysis examining the impacts of implementation phase and operational risks. The sensitivity analysis examined potential cost overruns and increases as well as significant reductions in the largest benefit categories. The results showed that the Project's net present value of benefits are robust and can withstand these stress events given the uncertainties that may arise, and still be economically viable over this period.

Table 26: Living Breakwaters Project - Benefit Cost Analysis Summary
Constant 2016 US Dollars

	Cumulative Present Values (2016-2066) At Discount Rates of:	
	7%	**3%**
LIFECYCLE COSTS		
Project Investment Costs \a	$54,909,955	$61,150,787
Operations & Maintenance (O&M)		
Maintenance	$7,080,207	$14,507,755
Monitoring	$453,411	$829,867
Total O&M	$7,533,618	$15,337,622
Total Costs	**$62,443,573**	**$76,488,409**
BENEFITS		
Resiliency Values		
Avoided Property Damages	$4,888,646	$12,645,701
Avoided Casualties (Mortality & Injuries)	$2,859,166	$5,858,597
Avoided Mental Health Treatment Costs	$506,972	$965,226
Avoided Lost Productivity Costs	$1,128,405	$2,148,374
Avoided shoreline erosion/dune reconstruction costs	$41,858,316	$56,815,891
Avoided displacement/disruption costs	$526,326	$1,376,525
Avoided Road Closure/Travel Disruption costs	$315,901	$647,300
Avoided Cost of Power Outages	$1,050,543	$2,152,587
Avoided Vehicle Damages	$63,787	$189,399
Total Resiliency Values	$53,198,061	$82,799,601
Environmental Values		
Total Gross Ecosystem Annual Service Gains (+)	$11,860,749	$24,625,205
Total Ecosystem Annual Services Displaced (-)	$264,537	$509,059
Net Ecosystem Annual Service Gains	$11,596,212	$24,116,146
Social Values		
Educational/Environmental Stewardship	$1,253,995	$2,569,509
Recreation	$7,095,681	$14,539,461
Total Social Values	$8,349,676	$17,108,970
Economic Revitalization Benefits		
Property Value Impacts (∫[Distance and Beach Width])	$2,953,868	$6,052,646
Total Benefits	**$76,097,817**	**$130,077,363**
Benefits less Costs (Net Present Value)	**$13,654,244**	**$53,588,954**
Benefit Cost Ratio (BCR)	**1.22**	**1.70**

Notes: Includes adjustment over time for 30 inch Sea Level Rise (SLR) \a Note that because Project construction is anticipated to occur over 2018, 2019 and the first quarter of 2020, the present value calculation of costs (as of 2016) will appear to be lower than the nominal project investment costs shown in the Opinion of Probable Cost Document due to the application of the 7% HUD recommended discount rate		

Figure 9



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Living Breakwaters Project - BCA Project Resource Statement (2016-2024)
constant 2016 US Dollars

	0	1	2	3	4	5	6	7	8
	Year		**Construction**		**Construction (Q2:2020):**	**Operations (Q2 2020)..... ===>**			
HUD Guidance Categories	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
LIFECYCLE COSTS			**CAPEX Phasing**						
Percent Installed, %			26%	63%	11%				
Project Investment Costs	$0.00	$0.00	$17,500,000	$42,000,000	$7,000,000	$0.0	$0.0	$0.0	$0.0
Operations & Maintenance									
Maintenance	$0.00	$0.00	$0.00	$0.00	$633,495	$633,495	$633,495	$633,495	$633,495
Monitoring	$0.00	$0.00	$0.00	$0.00	$75,000	$75,000	$75,000	$75,000	$75,000
Total O&M	$0.00	$0	$0	$0	$708,495	$708,495	$708,495	$708,495	$708,495
Total Costs	$0.00	$0	$17,500,000	$42,000,000	$7,708,495	$708,495	$708,495	$708,495	$708,495
BENEFITS									
Resiliency Values	$0	$0	$0	$0	$22,660,245	$931,222	$800,477	$818,763	$22,880,477
Avoided Property Damages	$0	$0	$0	$0	$181,012	$201,948	$222,885	$243,821	$264,758
Avoided Casualties (Mortality & Injuries)	$0.00	$0.00	$0.00	$0.00	$255,821	$255,821	$255,821	$255,821	$255,821
Avoided Mental Health Treatment Costs	$0	$0	$0	$0	$57,734	$55,733	$53,946	$52,341	$50,891
Avoided Lost Productivity Costs	$0	$0	$0	$0	$128,502	$124,049	$120,072	$116,499	$113,272
Avoided shoreline erosion/dune reconstruction costs	$0	$0	$0	$0	$21,894,480	$148,446	$0	$0	$22,042,926
Avoided displacement/disruption costs	$0	$0	$0	$0	$18,020	$20,394	$22,768	$25,142	$27,516
Avoided Road Closure/Travel Disruption costs	$0	$0	$0	$0	$28,265	$28,265	$28,265	$28,265	$28,265
Avoided Cost of Power Outages	$0	$0	$0	$0	$94,013	$94,009	$94,005	$94,001	$93,997
Avoided Vehicle Damages	$0	$0	$0	$0	$2,398	$2,557	$2,715	$2,873	$3,032
Environmental Values									
Total Gross Ecosystem Annual Service Gains (+)	$0	$0	$0	$0	$748,673	$946,097	$1,094,272	$1,094,272	$1,094,272
Total Ecosystem Annual Services Displaced (-)	$0	$0	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561
Net Ecosystem Annual Service Gains	$0	$0	-$20,561	-$20,561	$728,113	$925,537	$1,073,711	$1,073,711	$1,073,711
Social Values									
Educational/Environmental Stewardship	$0.00	$0.00	$0.00	$0.00	$112,200	$112,200	$112,200	$112,200	$112,200
Recreation	$0	$0	$0	$0	$634,879	$634,879	$634,879	$634,879	$634,879
Economic Revitalization Benefits									
Property Value Impacts (∫[Distance and Beach Width])	$0	$0	$0	$0	$264,294	$264,294	$264,294	$264,294	$264,294
Total Benefits	$0	$0	-$20,561	-$20,561	$24,399,731	$2,868,132	$2,885,561	$2,903,848	$24,965,561
Benefits less Costs	$0.00	$0	-$17,520,561	-$42,020,561	$16,691,237	$2,159,637	$2,177,066	$2,195,353	$24,257,066

Living Breakwaters Project - BCA Project Resource Statement (2025-2033) constant 2016 US Dollars									
	9	10	11	12	13	14	15	16	17
HUD Guidance Categories	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
LIFECYCLE COSTS									
Percent Installed, %									
Project Investment Costs	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Operations & Maintenance									
Maintenance	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495
Monitoring	$0.00	$0.00	$0.00	$0.00	$150,000	$0.00	$0.00	$0.00	$0.00
Total O&M	$633,495	$633,495	$633,495	$633,495	$783,495	$633,495	$633,495	$633,495	$633,495
Total Costs	$633,495	$633,495	$633,495	$633,495	$783,495	$633,495	$633,495	$633,495	$633,495
BENEFITS									
Resiliency Values	$856,769	$3,599,366	$1,044,736	$22,810,981	$936,966	$1,106,102	$978,546	$999,616	$1,169,294
Avoided Property Damages	$285,694	$306,631	$327,568	$348,504	$369,441	$390,377	$411,314	$432,250	$453,187
Avoided Casualties (Mortality & Injuries)	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821
Avoided Mental Health Treatment Costs	$49,575	$48,374	$47,275	$46,266	$45,334	$44,473	$43,673	$42,930	$42,236
Avoided Lost Productivity Costs	$110,342	$107,670	$105,224	$102,977	$100,904	$98,986	$97,207	$95,552	$94,009
Avoided shoreline erosion/dune reconstruction costs	$0	$2,723,000	$148,446	$21,894,480	$0	$148,446	$0	$0	$148,446
Avoided displacement/disruption costs	$29,890	$32,264	$34,638	$37,012	$39,386	$41,760	$44,134	$46,508	$48,882
Avoided Road Closure/Travel Disruption costs	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265
Avoided Cost of Power Outages	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992
Avoided Vehicle Damages	$3,190	$3,348	$3,506	$3,665	$3,823	$3,981	$4,139	$4,298	$4,456
Environmental Values									
Total Gross Ecosystem Annual Service Gains (+)	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272
Total Ecosystem Annual Services Displaced (-)	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561
Net Ecosystem Annual Service Gains	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711
Social Values									
Educational/Environmental Stewardship	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200
Recreation	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879
Economic Revitalization Benefits									
Property Value Impacts (∫[Distance and Beach Width])	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294
Total Benefits	$2,941,853	$5,684,450	$3,129,820	$24,896,065	$3,022,050	$3,191,186	$3,063,630	$3,084,701	$3,254,379
Benefits less Costs	$2,308,359	$5,050,955	$2,496,326	$24,262,571	$2,238,555	$2,557,691	$2,430,136	$2,451,206	$2,620,884

Living Breakwaters Project - BCA Project Resource Statement (2034-2042)
constant 2016 US Dollars

	18	19	20	21	22	23	24	25	26
HUD Guidance Categories	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**
LIFECYCLE COSTS									
Percent Installed, %									
Project Investment Costs	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Operations & Maintenance									
Maintenance	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495
Monitoring	$150,000	$0.00	$0.00	$0.00	$0.00	$150,000	$0.00	$0.00	$0.00
Total O&M	$783,495	$633,495	$633,495	$633,495	$633,495	$783,495	$633,495	$633,495	$633,495
Total Costs	$783,495	$633,495	$633,495	$633,495	$633,495	$783,495	$633,495	$633,495	$633,495
BENEFITS									
Resiliency Values	$1,042,226	$3,786,735	$1,233,811	$1,107,104	$1,128,942	$1,299,318	$1,172,886	$1,194,977	$1,365,585
Avoided Property Damages	$474,123	$495,060	$515,997	$536,933	$557,870	$578,806	$599,743	$620,679	$641,616
Avoided Casualties (Mortality & Injuries)	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821
Avoided Mental Health Treatment Costs	$41,588	$40,981	$40,411	$39,874	$39,369	$38,892	$38,441	$38,014	$37,608
Avoided Lost Productivity Costs	$92,566	$91,214	$89,945	$88,751	$87,626	$86,564	$85,560	$84,610	$83,708
Avoided shoreline erosion/dune reconstruction costs	$0	$2,723,000	$148,446	$0	$0	$148,446	$0	$0	$148,446
Avoided displacement/disruption costs	$51,256	$53,630	$56,004	$58,378	$60,752	$63,126	$65,500	$67,874	$70,248
Avoided Road Closure/Travel Disruption costs	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265
Avoided Cost of Power Outages	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992
Avoided Vehicle Damages	$4,614	$4,772	$4,931	$5,089	$5,247	$5,405	$5,564	$5,722	$5,880
Environmental Values									
Total Gross Ecosystem Annual Service Gains (+)	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272
Total Ecosystem Annual Services Displaced (-)	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561
Net Ecosystem Annual Service Gains	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711
Social Values									
Educational/Environmental Stewardship	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200
Recreation	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879
Economic Revitalization Benefits									
Property Value Impacts (∫[Distance and Beach Width])	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294
Total Benefits	$3,127,310	$5,871,819	$3,318,895	$3,192,188	$3,214,026	$3,384,402	$3,257,970	$3,280,061	$3,450,669
Benefits less Costs	$2,343,816	$5,238,325	$2,685,401	$2,558,693	$2,580,532	$2,600,908	$2,624,475	$2,646,566	$2,817,175

Living Breakwaters Project - BCA Project Resource Statement (2043-2051)
constant 2016 US Dollars

	27	28	29	30	31	32	33	34	35
HUD Guidance Categories	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**	**2051**
LIFECYCLE COSTS									
Percent Installed, %									
Project Investment Costs	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Operations & Maintenance									
Maintenance	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495
Monitoring	$0.00	$150,000	$0.00	$0.00	$0.00	$0.00	$150,000	$0.00	$0.00
Total O&M	$633,495	$783,495	$633,495	$633,495	$633,495	$633,495	$783,495	$633,495	$633,495
Total Costs	$633,495	$783,495	$633,495	$633,495	$633,495	$633,495	$783,495	$633,495	$633,495
BENEFITS									
Resiliency Values	$1,239,367	$1,261,656	$1,432,447	$1,312,575	$1,335,534	$1,506,983	$1,381,584	$1,404,670	$1,576,240
Avoided Property Damages	$662,552	$683,489	$704,426	$725,362	$746,299	$767,235	$788,172	$809,108	$830,045
Avoided Casualties (Mortality & Injuries)	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821
Avoided Mental Health Treatment Costs	$37,224	$36,858	$36,510	$36,178	$35,861	$35,559	$35,270	$34,993	$34,727
Avoided Lost Productivity Costs	$82,852	$82,038	$81,263	$80,524	$79,819	$79,146	$78,502	$77,886	$77,295
Avoided shoreline erosion/dune reconstruction costs	$0	$0	$148,446	$0	$0	$148,446	$0	$0	$148,446
Avoided displacement/disruption costs	$72,622	$74,996	$77,370	$79,744	$82,118	$84,492	$86,866	$89,240	$91,614
Avoided Road Closure/Travel Disruption costs	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265
Avoided Cost of Power Outages	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992
Avoided Vehicle Damages	$6,038	$6,197	$6,355	$12,689	$13,358	$14,027	$14,697	$15,366	$16,035
Environmental Values									
Total Gross Ecosystem Annual Service Gains (+)	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272
Total Ecosystem Annual Services Displaced (-)	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561
Net Ecosystem Annual Service Gains	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711
Social Values									
Educational/Environmental Stewardship	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200
Recreation	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879
Economic Revitalization Benefits									
Property Value Impacts (∫[Distance and Beach Width])	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294
Total Benefits	$3,324,451	$3,346,740	$3,517,532	$3,397,660	$3,420,618	$3,592,068	$3,466,668	$3,489,755	$3,661,325
Benefits less Costs	$2,690,957	$2,563,246	$2,884,037	$2,764,165	$2,787,123	$2,958,573	$2,683,174	$2,856,260	$3,027,830

Living Breakwaters Project - BCA Project Resource Statement (2052-2060)
constant 2016 US Dollars

	36	37	38	39	40	41	42	43	44
HUD Guidance Categories	**2052**	**2053**	**2054**	**2055**	**2056**	**2057**	**2058**	**2059**	**2060**
LIFECYCLE COSTS									
Percent Installed, %									
Project Investment Costs	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Operations & Maintenance									
Maintenance	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495
Monitoring	$0.00	$0.00	$150,000	$0.00	$0.00	$0.00	$0.00	$150,000	$0.00
Total O&M	$633,495	$633,495	$783,495	$633,495	$633,495	$633,495	$633,495	$783,495	$633,495
Total Costs	$633,495	$633,495	$783,495	$633,495	$633,495	$633,495	$633,495	$783,495	$633,495
BENEFITS									
Resiliency Values	$1,450,953	$1,474,146	$1,645,815	$1,520,621	$1,543,901	$1,715,654	$1,590,538	$1,613,892	$1,785,714
Avoided Property Damages	$850,982	$871,918	$892,855	$913,791	$934,728	$955,664	$976,601	$997,537	$1,018,474
Avoided Casualties (Mortality & Injuries)	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821
Avoided Mental Health Treatment Costs	$34,473	$34,229	$33,994	$33,769	$33,552	$33,343	$33,142	$32,948	$32,761
Avoided Lost Productivity Costs	$76,729	$76,186	$75,664	$75,162	$74,679	$74,215	$73,767	$73,335	$72,919
Avoided shoreline erosion/dune reconstruction costs	$0	$0	$148,446	$0	$0	$148,446	$0	$0	$148,446
Avoided displacement/disruption costs	$93,988	$96,362	$98,736	$101,109	$103,483	$105,857	$108,231	$110,605	$112,979
Avoided Road Closure/Travel Disruption costs	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265
Avoided Cost of Power Outages	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992
Avoided Vehicle Damages	$16,704	$17,373	$18,042	$18,711	$19,380	$20,049	$20,719	$21,388	$22,057
Environmental Values									
Total Gross Ecosystem Annual Service Gains (+)	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272
Total Ecosystem Annual Services Displaced (-)	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561
Net Ecosystem Annual Service Gains	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711
Social Values									
Educational/Environmental Stewardship	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200
Recreation	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879
Economic Revitalization Benefits									
Property Value Impacts (∫[Distance and Beach Width])	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294
Total Benefits	$3,536,038	$3,559,230	$3,730,899	$3,605,706	$3,628,986	$3,800,738	$3,675,623	$3,698,977	$3,870,799
Benefits less Costs	$2,902,543	$2,925,735	$2,947,405	$2,972,211	$2,995,491	$3,167,243	$3,042,128	$2,915,482	$3,237,304

Living Breakwaters Project - BCA Project Resource Statement (2061-2066)

constant 2016 US Dollars

	45	46	47	48	49	50
HUD Guidance Categories	**2061**	**2062**	**2063**	**2064**	**2065**	**2066**
LIFECYCLE COSTS						
Percent Installed, %						
Project Investment Costs	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Operations & Maintenance						
Maintenance	$633,495	$633,495	$633,495	$633,495	$633,495	$633,495
Monitoring	$0.00	$0.00	$0.00	$150,000	$0.00	$0.00
Total O&M	$633,495	$633,495	$633,495	$783,495	$633,495	$633,495
Total Costs	$633,495	$633,495	$633,495	$783,495	$633,495	$633,495
BENEFITS						
Resiliency Values	$1,660,665	$1,684,082	$1,855,964	$1,730,972	$1,754,443	$1,926,376
Avoided Property Damages	$1,039,411	$1,060,347	$1,081,284	$1,102,220	$1,123,157	$1,144,093
Avoided Casualties (Mortality & Injuries)	$255,821	$255,821	$255,821	$255,821	$255,821	$255,821
Avoided Mental Health Treatment Costs	$32,580	$32,406	$32,237	$32,074	$31,917	$31,764
Avoided Lost Productivity Costs	$72,517	$72,128	$71,753	$71,390	$71,039	$70,699
Avoided shoreline erosion/dune reconstruction costs	$0	$0	$148,446	$0	$0	$148,446
Avoided displacement/disruption costs	$115,353	$117,727	$120,101	$122,475	$124,849	$127,223
Avoided Road Closure/Travel Disruption costs	$28,265	$28,265	$28,265	$28,265	$28,265	$28,265
Avoided Cost of Power Outages	$93,992	$93,992	$93,992	$93,992	$93,992	$93,992
Avoided Vehicle Damages	$22,726	$23,395	$24,064	$24,733	$25,402	$26,071
Environmental Values						
Total Gross Ecosystem Annual Service Gains (+)	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272	$1,094,272
Total Ecosystem Annual Services Displaced (-)	$20,561	$20,561	$20,561	$20,561	$20,561	$20,561
Net Ecosystem Annual Service Gains	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711	$1,073,711
Social Values						
Educational/Environmental Stewardship	$112,200	$112,200	$112,200	$112,200	$112,200	$112,200
Recreation	$634,879	$634,879	$634,879	$634,879	$634,879	$634,879
Economic Revitalization Benefits						
Property Value Impacts (∫[Distance and Beach Width])	$264,294	$264,294	$264,294	$264,294	$264,294	$264,294
Total Benefits	$3,745,750	$3,769,167	$3,941,049	$3,816,056	$3,839,527	$4,011,460
Benefits less Costs	$3,112,255	$3,135,672	$3,307,554	$3,032,562	$3,206,032	$3,377,966

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Attachment A: Parameters and Assumptions:

Living Breakwaters & Tottenville Shoreline Protection Schematic Design: Standards & Assumptions For Project Screening And 30% Design, v. 4

MEMO

Date: September 29, 2016

From: Pippa Brashear / SCAPE

To: Living Breakwaters & Tottenville Shoreline Protection Design and EIS teams / GOSR, AKRF, STANTEC TEAM

Cc: SCAPE, OCC/COWI, ARCADIS, PB, MFS, SEARC, NYHF, Prudent (SCAPE team)

Re: **Living Breakwaters & Tottenville Shoreline Protection Schematic Design: Standards & Assumptions For Project Screening And 30% Design, v. 4**

Previous Versions

Version	date	notes
1	9/29/2015	based on the team meeting Friday 6/5/2015 ,SCAPE and AKRF team member conversation regarding climate change assumptions on 7/10, internal review by the SCAPE and Stantec Design teams, and a final conversation among GOSR, ARKF and the SCAPE and Stantec design teams on 8/21/2015
2	11/09/2015	Updated to include shoreline definition and existing topography assumptions. Changes reviewed and approved by project team.
3	6/10/2016	Updated to include detail on storm scenario selection and refined parameters for hydrodynamic modeling assumptions. The Shoreline definition was also update based on LB and TSP team work to date.
4	9/08/2016	Updated to include wave and water level table and sediment grain size table as well as Updated to include data used for screening for Shoreline Protection project.

This document contains a summary of the latest project assumptions and parameters that are to be used for the initial analysis and screening of alternatives and for 30% Design for both the Living Breakwaters (LBW) and Tottenville Shoreline Protection Projects (TSPP). This is a living document to help in coordination among the Living Breakwaters and Tottenville Shoreline Protection Design Teams as well as the joint project EIS team.

Contents

Figures

Tables

Survey & Mapping Standards

Vertical Datum: North American Vertical Datum of 1988 (NAVD88), Geoid 2012A *(this is consistent with the initial bathymetric survey already completed by Hill/ASI)*. All elevations and survey data are to be provided relative to this datum.

Horizontal Control Datum: North American Datum of 1983 (NAD 83)

Coordinate System / Projection for printed maps: New York Long Island State Plane FIPS 3104 (US survey feet)

Project stationing: Project station locations and alignments to be established for the combined Living Breakwater and Shoreline Protection projects. These are tbd. Surveying teams to include monumentation in their survey work (to be decided / confirmed by GOSR).

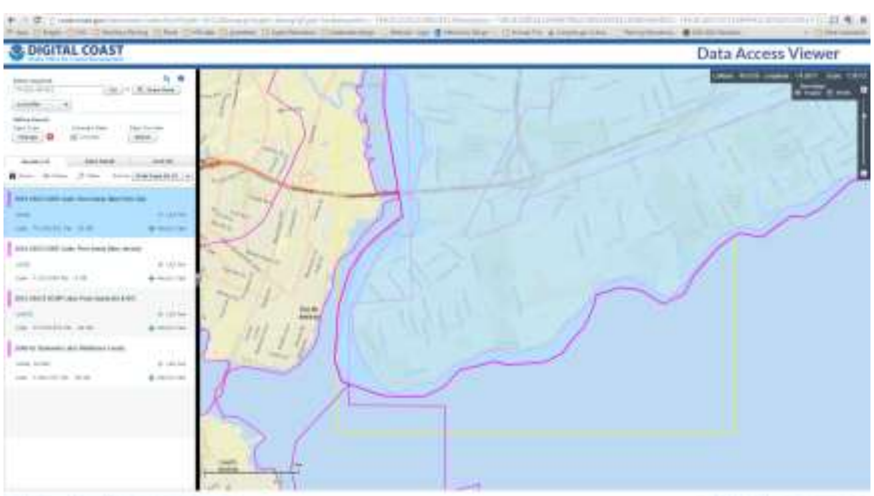
Metadata requirements: All data and field survey results to be accompanied with complete metadata; metadata standards to be developed and agreed upon by team.

Elevation Data

Within the project area, the following sources are being used for bathymetric and topographic information:

- **Bathymetry:** June 2015 Bathymetric survey performed by Hill/ASI.
- **Topograpy:** Fall 2015 land-side topographic and boundary surveys performed by Naik for the Stantec Team (for Tottenville Shoreline Protection Area only).
- **Beach profile transects**
  - November 2015 beach profile transect surveys performed by MFS Engineers and Prudent Engineering
  - May 2016 beach profile transect surveys performed by MFS Engineers and Prudent Engineering.
- For areas outside the Tottenville Shoreline Protection survey area, land-side topographic information will be based on the 2014 USGS CGM LiDAR: Post Sandy for New York City, available for download from the NOAA Digital Coast viewer (screenshot below). Metadata for this topography information is available here.

Figure 1. ***Source for 2014 USGS CGM LiDAR data***



Sediment Characterization

Within the project area, the following sources are being used for sediment information:

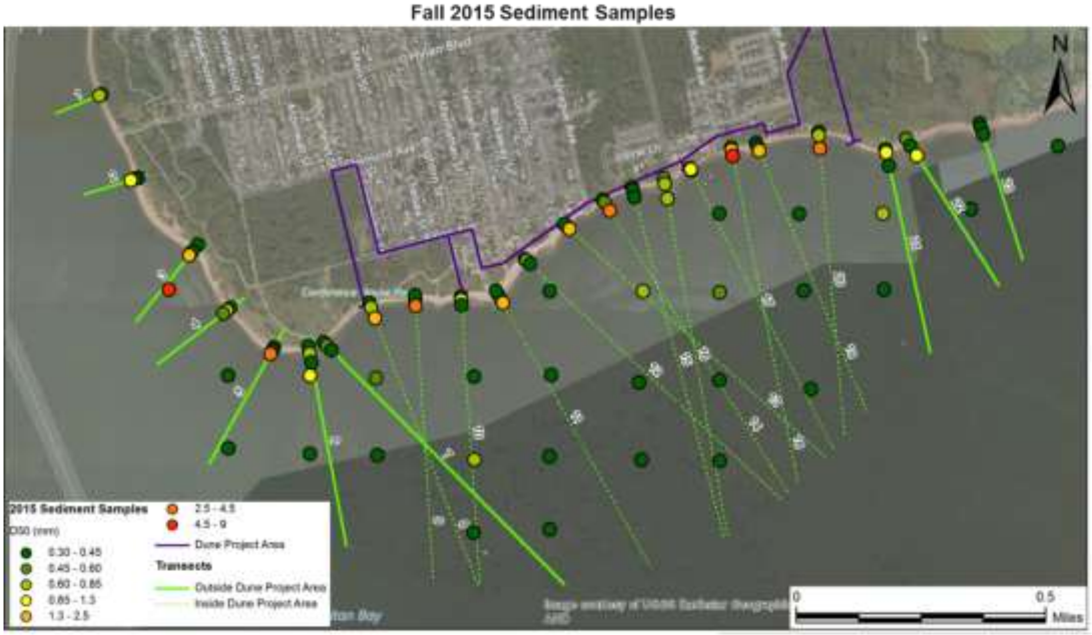
- Sediment grab samples and analysis performed at 28 in water locations throughout the project area by Hill/ASI in June 2015.
- Sediment grab samples along the beach survey transects in 72 locations by MFS in December 2015
- Geotechnical borings in the potential breakwater construction region were taken at 20 locations to depths of 52-105 feet in November 2015
- Sediment grab samples taken at 39 in water locations by Prudent and 78 beach locations by MFS along the 23 survey transects in April/May 2016

The above sediment sample results can all be downloaded from the project sharepoint site.

The sediment data is summarized in the following figures and table. Average grain sizes are the provided for the entire data set along each survey transect and also with the coarsest grain sizes observed at MLW removed.

Figure 2. ***Fall 2015 and Spring 2016 Sediment Sampling Results***

Fall 2015 Sediment Samples



Spring 2016 Sediment Samples

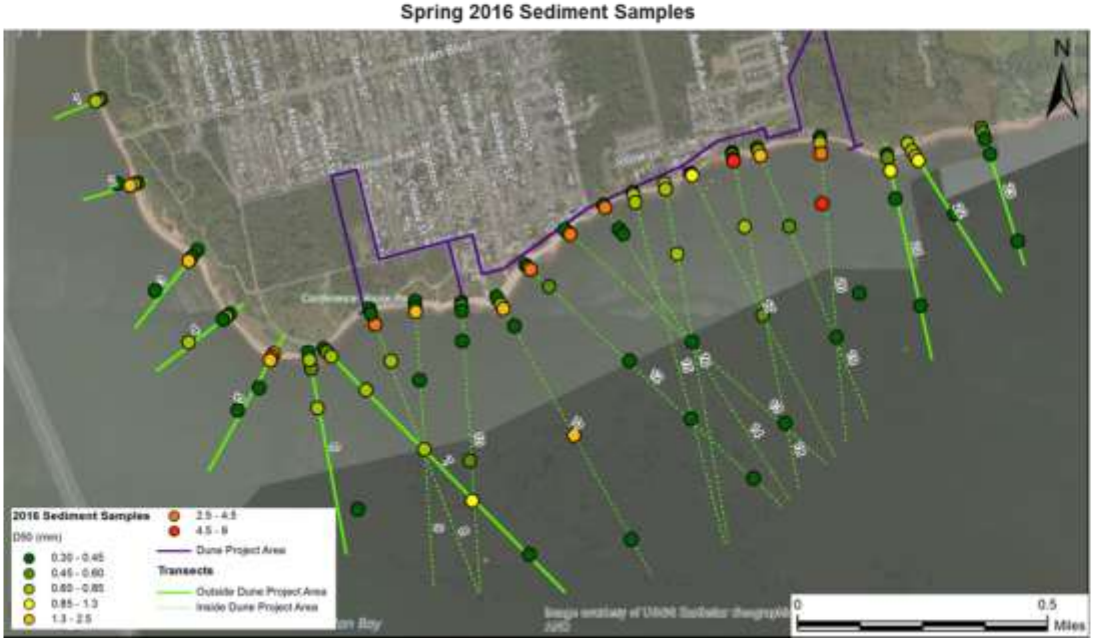


Table 1. Summary Of Average Grain Sizes By Transect

Transect	Average D50 of Samples (mm)			Average D50 Excluding MLW Sample Locations (mm)		
	Fall 2015	Spring 2016	Average	Fall 2015	Spring 2016	Average
1	0.64	0.68	0.66	0.64	0.66	0.65
2	0.66	0.67	0.67	0.34	0.38	0.36
3	1.93	0.60	1.27	1.91	0.30	1.11
4	0.62	0.54	0.58	0.66	0.57	0.62
5	1.00	2.04	1.52	0.25	1.98	1.11
6	0.54	0.52	0.53	0.58	0.52	0.55
7	0.44	0.59	0.51	0.45	0.58	0.51
8	0.84	1.02	0.93	0.42	0.49	0.46
9	1.18	0.53	0.85	0.40	0.33	0.36
10	0.46	0.38	0.42	0.54	0.42	0.48
11	0.62	0.88	0.75	0.40	0.65	0.53
12	0.31	0.91	0.61	0.37	0.41	0.39
13	0.65	0.79	0.72	0.42	0.34	0.38
14	1.10	3.21	2.16	0.48	1.15	0.81
15	0.40	0.63	0.52	0.41	0.56	0.48
16	0.53	0.65	0.59	0.45	0.65	0.55
17	2.18	1.02	1.60	0.47	0.98	0.72
18	3.67	1.30	2.48	1.26	0.56	0.91
19	0.82	0.70	0.76	0.40	0.51	0.45
20	1.88	2.03	1.95	0.57	1.91	1.24
21	0.68	0.50	0.59	0.77	0.37	0.57
22	0.52	0.71	0.61	0.36	0.61	0.49
23	0.30	0.41	0.35	0.30	0.42	0.36
Average	**0.95**	**0.93**	**0.94**	**0.56**	**0.67**	**0.61**

Shoreline Location

The “shoreline” will generally be shown as the current MHW line on maps.

For this project, unless otherwise indicated, Mean High Water (MHW) is defined to be MHW at the NOAA station at Sandy Hook, NJ (8531680) for the current epoch w (2.08 NAVD88). The current MHW line, is defined to be the intersection of this elevation with the on-land Bathymetry as surveyed by the Stantec team in the Fall of 2015 or, outside that area the 2014 USGS CGM LiDAR: Post Sandy for New York City

Historic shorelines were defined by the most recent high tide mark as delineated from historic orthoimagery. This was quantified by extracting the measured high tide at Sandy Hook for each orthoimage date. The average for all the orthoimages analyzed was 2.04 NAVD88, very close to the published MHW datum of 2.08 NAVD88.

Sometimes, for the purposes of mapping, the FEMA shoreline, as defined in the 2013 FEMA Preliminary FIRMs may be shown as a general reference.

Tidal Elevations

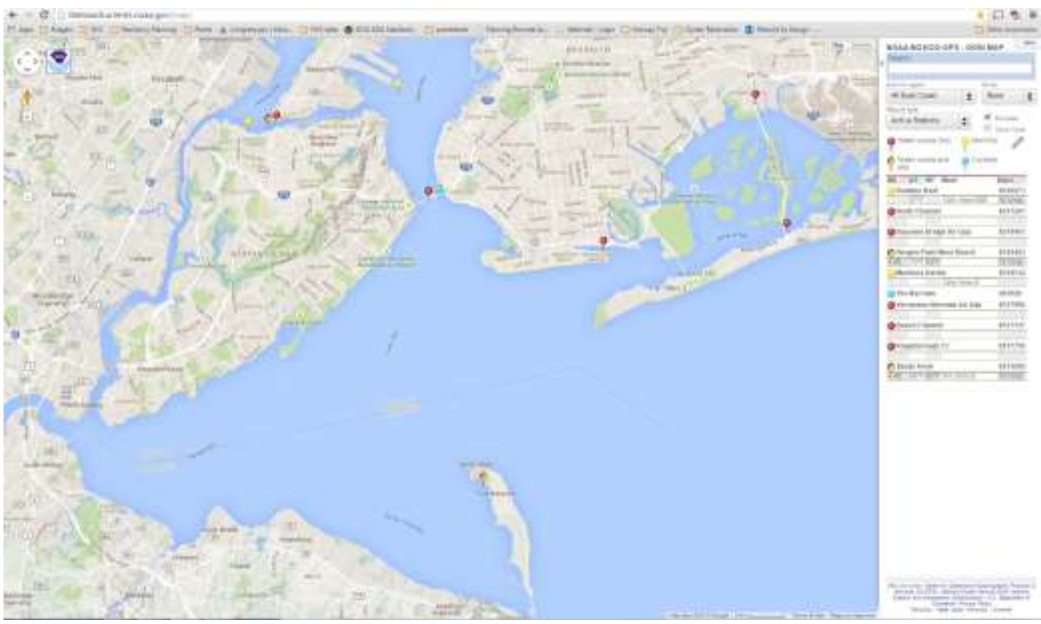
For the purposes of concept screening and schematic design, tides will be assumed to be those recorded at NOAA's Sandy Hook, NJ station (8531680), 1983-2001 epoch.

Table 2. Tidal elevations @ Sandy Hook (8531680)

Sandy Hook (8531680)	Station Datum	NAVD88
Station Datum	0	-5.33
NAVD88	5.33	0
HAT	9.11	3.78
MHHW	7.74	2.41
MHW	7.41	2.08
MSL	5.09	-0.24
MLW	2.71	-2.62
MLLW	2.51	-2.82
LAT	1.14	-4.19

Additional datums and complete station data is available online (http://tidesandcurrents.noaa.gov/datums.html?id=8531680). The online NOAA tides and current map (http://tidesandcurrents.noaa.gov/map/) indicates the Sandy Hook station is the closest station location with both tidal levels and meteorological data.

Figure 3. Map of NOAA data collection locations



Storm Return Periods

For the purpose of 30% design, the following storm return periods will be considered / studied:

- 10 year
- 25 year
- 50 year
- 100 year
- Hurricane Sandy

Storm time series of water levels and waves for 10, 25, 50, and 100-year events will be extracted from the storm surge and wave modeling (ADCIRC/SWAN) used by FEMA to develop the 2013 PFIRM and 2015 effective maps. Hurricane Sandy information will be taken from available existing ADCIRC modeling. Details of the storm set selection will be provided in the Living Breakwaters 30% Design Modeling Report.

The same return periods will be used for performance analysis of both the Living Breakwaters and Shoreline Protection. Alternative return periods may be analyzed if agreed upon by the Living Breakwaters and Shoreline Protection design project teams.

The source and reference information for the storms or suite of storms considered have been described, documented and agreed upon by the Living Breakwaters and Shoreline Protection design teams in coordination and consultation with each other. The agreed upon storm conditions in the project vicinity are provided in the table below.

Table 3. Water levels and wave heights for target storm events

		"today"		With 30" sea level rise	
Return Period	**% annual chance**	**stillwater elevation**	**significant wave height**	**stillwater elevation**	**significant wave height**
		NAVD88 (feet)	feet	NAVD88 (feet)	feet
10 YEAR	10%	8.1	3.9	10.6	3.9
25 YEAR	4%	9.3	4.3	11.8	4.3
50 YEAR	2%	11.3	4.9	13.8	4.9
100 YEAR	1%	12.9	5.3	15.4	5.3
SANDY	n/a	12.9	6.3	15.4	6.3
MHW	n/a	2.1	3.0	4.6	3.0

Early on, for initial concept development and screening, the assumed stillwater surge elevations for each storm return period was based on the stillwater elevations identified in the 2013 FEMA Flood Insurance Rate Study for New York City (FIS # 360497V000B, version 1.0.0.0).

The FEMA FIS transects associated with the project site include R-35, R-36, R-37, R-38 and R-39 and are noted below.

Figure 4. ***FEMA FIS Transect Locations***

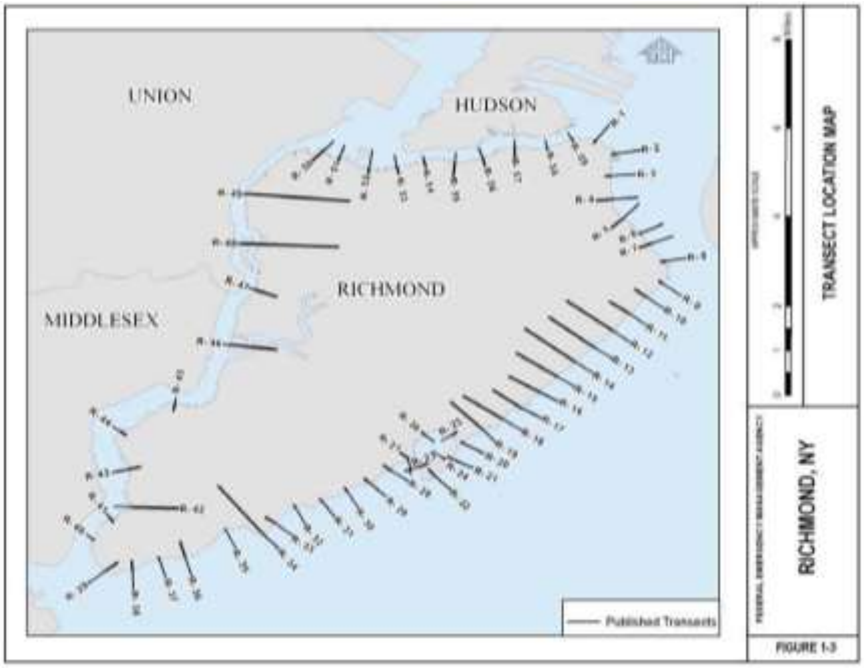


Figure 1-3: Richmond County published and mapping transect map

Table 4. ***FEMA FIS Transect Data***

Flood Source	Transect	Starting Wave Conditions for the 1% Annual Chance			Starting Stillwater Elevations[1] (ft NAVD88) Range of Stillwater Elevations[2] (ft NAVD88)			
		Coordinates	Significant Wave Height (ft)	Peak Wave Period (sec)	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Raritan Bay	R-28	N 40.532775 W 74.150388	6.36	6.83	7.6 0 - 0	10.7	12.1 12.1 - 12.2	15.7 15.7 - 16.1
Raritan Bay	R-29	N 40.528419 W 74.157873	6.37	6.15	7.7	10.8	12.3	15.8
Raritan Bay	R-30	N 40.525471 W 74.166748	7.30	6.44	7.8	10.9	12.3	15.8
Raritan Bay	R-31	N 40.521914 W 74.174300	7.42	6.08	7.8	10.9	12.4	15.9
Raritan Bay	R-32	N 40.519829 W 74.183611	7.53	6.09	7.8	11	12.4	16
Raritan Bay	R-33	N 40.514262 W 74.190726	7.53	5.93	7.8 7.7 - 7.8	11	12.4 12.3 - 12.4	16 16 - 16.6
Raritan Bay	R-34	N 40.510220 W 74.194769	6.10	4.72	7.9 7.7 - 7.9	11 10.9 - 11	12.4 12.3 - 12.7	16 15.8 - 16.5
Raritan Bay	R-35	N 40.511679 W 74.208054	4.87	4.43	7.9	11.1	12.5	16.1
Raritan Bay	R-36	N 40.502497 W 74.222386	6.65	5.49	8 6.9 - 8.1	11.2	12.7 12.5 - 12.7	16.2 16.1 - 16.3
Raritan Bay	R-37	N 40.501746 W 74.231526	6.17	5.27	8.1	11.3	12.8	16.3
Raritan Bay	R-38	N 40.497605 W 74.240883	6.05	5.46	8.1 7.9 - 8.7	11.3	12.8 12.8 - 13	16.4 16.4 - 16.7
Raritan Bay	R-39	N 40.497433 W 74.250294	4.71	4.75	8.2 6.8 - 8.3	11.4 11.3 - 11.4	12.9 12.8 - 12.9	16.4 16.4 - 16.8
Arthur Kill	R-40	N 40.508668 W 74.254714	1.47	2.17	8.2	11.4	12.8	16.2
Arthur Kill	R-41	N 40.516106 W 74.248753	3.15	3.67	8.2	11.3 11.2 - 11.3	12.7 12.6 - 12.7	16.1 16 - 16.1

[1]Stillwater elevations include the contribution from wave setup.
[2]For transects with a constant stillwater elevation, only one number is provided to represent both the starting value and the range.

Source: 2013 FEMA Flood Insurance Rate Study for New York City (FIS # 360497V000B, version 1.0.0.0)

Living Breakwaters Analysis of system response to Storm WaveS

The Living Breakwaters team will utilize the water levels, wave heights and storm hydrographs associated with these storms to inform wave refraction and diffraction modeling of the breakwaters system during storm events as well as anticipated wave transmission for the breakwater systems. This information will also be used to inform event-based erosion modeling using SBEACH or CSHORE for locations outside the TSPP project area (within the TSPP project area, analysis will be performed by the TSPP team). Event-based erosion modeling by the Living Breakwaters team will be calibrated using pre- and post- Sandy LiDAR data.

TSPP Analysis of system response to Storm WaveS

The Shoreline Protection features will be analyzed for wave runup, overtopping, and localized scour/erosion for the 10, 25, 50, and 100-year storm events. The water elevations and wave time series for this analysis will be the same as used for the LBW project design. Initial assessment will be based on the condition of no LBW case. Stone and structural components will be sized for stability under the 100-year event, however sand cover and surficial components may experience erosion. Since the crest elevation has already been determined based on existing topographic features, the applicable return period for which the Shoreline Protection features influence runup and overtopping will be calculated.

Revetment and stone core bottom of toe elevations will be based upon estimates for scour potential upon guidance within the USACE Coastal Engineering Manual (CEM). SBEACH will also be used to compare erosion potential. SBEACH analysis will be based upon grain size analysis and wave time series d noted in other sections herein. Other SBEACH parameters for 30% design will follow USACE South Shore of Staten Island, New York, Coastal Storm Risk Management, Fort Wadsworth to Oakwood Beach, Draft Main Report, June 2015.

Prior TSPP analysis

The Shoreline Protection alternative was previously assessed during screening of design options for the 1, 10, 25, 50, and 100-year recurrence interval environmental conditions, i.e. winds, water surface elevation, and waves, to be used for comparison with the performance dune reinforced with stone core (herein referred to as hybrid dune) and of a levee alternative. The maximum significant wave height, peak wave period, water level, and wind speeds associated with the initial screening of each of these storm events is summarized in the table below:

Table 5. Summary of storm information use for TSPP initial screening (superseded by information in table 3 for 30% design)

Return Period (yr)	Design (FEMA) Water Level (ft NAVD 88)	Design Water Level Water Level + 30" SLR (ft NAVD 88)	ACES Calculated Wave Height (ft)	ACES Calculated Wave Period (sec)	Wind Speed (mph)
100	12.8	15.3	8.4	5.31	96
50	11.3	13.8	7.66	5.1	90
25	9.9	12.4	6.92	4.87	85
10	8.1	10.6	6.02	4.58	76
1	3.4	5.9	3.9	3.79	55

This preliminary screening included the assessment of hybrid dunes and a levee option. Based upon this assessment, the levee alternative was not pursued for further design. Following this initial assessment, the hybrid dune elevation was set based upon site constraints and the linear extend of the stone core dune was revised. Adjoining the stone core dune, areas of eco-revetment, earthen berm, and raised pathway (collectively shoreline protection features) were incorporated along reaches of shoreline.

Long Term Shoreline Change

Historic shoreline change was analyzed using aerial imagery obtained from the New York State Department of Environmental Conservation (DEC) and New York City Department of Information Technology and Telecommunications (DOITT).

Projected long term shoreline change is being analyzed using the GENESIS shoreline change model.

Wave climate assumptions for this modeling is based on available USACE offshore wave hindcast data and/or measured wave data. Hourly wave data were transformed by the Living Breakwaters project team from offshore to the project site using the numerical model SWAN for the available time period of 1982-2012. A description of the methodology used will be provided in the Living Breakwaters will be provided in the Living Breakwaters 30% Design Modeling Report. .

Sea Level Rise

For the purpose of initial screening and analysis and 30% design, a single sea level rise assumption will be made. Once a preferred breakwater design or limited number of design scenarios are arrived at, performance under additional SLR scenarios may be studied.

The following assumption for Sea Level Rise will be made for the purpose of developing, analyzing and screening design scenarios for 30% design (for both the Living Breakwaters and Shoreline Protections): **30 inches**.

This is consistent with a mid-range SLR projection for the 2080s according to the New York City Panel on Climate Change (NPCC). The 2080s projection was selected because it is the closest projection window to the projects target completion year (2020) plus assumed design life (50 years), 2070. This SLR is also consistent with the NPCCs 90th percentile estimate for 2050, ensuring that the high SLR estimate for the first half of the design life is accounted for. See the NPCC SLR projections below for reference)

Table 6. New York City Sea Level Rise Projections

Baseline (2000–2004) 0 in	Low estimate (10th percentile)	Middle range (25th to 75th percentile)	High estimate (90th percentile)
2020s	2 in	4–8 in	10 in
2050s	8 in	11–21 in	30 in
2080s	13 in	18–39 in	58 in
2100	15 in	22–50 in	75 in

Note: Projections are based on a six-component approach that incorporates both local and global factors. The model-based components are from 24 global climate models and two representative concentration pathways. Projections are relative to the 2000–2004 base period.

Source: Ann. N.Y. Acad. Sci. ISSN 0077-8923; "New York City Panel on Climate Change 2015 Report, Chapter 2: Sea Level Rise and Coastal Storms" by Radley Horton, Christopher Little, Vivien Gornitz, Daniel Bader, and Michael Oppenheimer. http://onlinelibrary.wiley.com/doi/10.1111/nyas.12593/epdf

Project Design life

Living Breakwaters

For the purposes of developing and screening initial Living Breakwaters design concepts, the target functional design life will be 50 years. This does not mean that it is assumed that the Living Breakwaters will fail or cease to function after 50 years, but simply that this is the period over which we hope to maintain desired performance. After 50 years it is assumed that the Living Breakwaters would be able to be upgraded or adapted to maintain performance over a longer timeframe. This assumption is made for the purposes of initial analysis and screening, in developing the preferred scenario(s) the different project functional and structural design lives may be explored and analyzed.

Tottenville Shoreline Protection Project

The rock core of the Shoreline Protection structure will be considered for a 50-yr design life. It should be noted for the Shoreline Protection alternative that periodic nourishment of the beach and Shoreline Protection may be required within the project life span. Such nourishment requirements will be assessed as part of this effort and will need to be considered as operational and maintenance costs associated with this alternative.